ENCYCLOPEDIA OF DIET

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A Treatise on the Food Question

IN FIVE VOLUMES

EXPLAINING, IN PLAIN LANGUAGE, THE CHEMISTRY OF FOOD AND THE CHEMISTRY OF THE HUMAN BODY, TOGETHER WITH THE ART OF UNITING THESE TWO BRANCHES OF SCIENCE IN THE PROCESS OF EATING SO AS TO ESTABLISH NORMAL DIGESTION AND ASSIMILATION OF FOOD AND NORMAL ELIMINATION OF WASTE, THEREBY REMOVING THE CAUSES OF STOMACH, INTESTINAL, AND ALL OTHER DIGESTIVE DISORDERS

BY

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VOLUME I

NEW YORK CITY
CORRECTIVE EATING SOCIETY, Inc.
1917

PUBLISHED AUGUST, 1914

TO THE

MOTHERS

AND TO THE NOBLE WORKERS

IN THE GREAT CAUSE OF HUMAN HEALTH

AND OF HUMAN SUFFERING

THESE VOLUMES ARE

Dedicated

BY

THE AUTHOR

PREFACE

Countless centuries have come and gone and have left on the earth myriad forms of life; but just what life is, from whence it came, whether or not there is purpose or design behind it, whether or not all the sacred books are mere conceptions of the infant mind, of the whence and whither, we do not know; but when we put life beneath the searchlight of science, we do know that it is a mere assembling of ionic matter into organic forms, and that this strange work is done in accordance with certain well-defined laws.

We know that these laws are a part of the great cosmic scheme. In harmony with them works evolution, which tends to lift to higher and higher degrees of perfection all forms of both animate and inanimate life. We believe that if all the natural laws governing life could be ascertained and obeyed, the number of disorders or interferences with Nature's scheme would be very greatly decreased.

Man's system of co-operating with his fellow-creatures, which we call civilization, has imposed certain restrictions, duties and limitations upon him, which make it impossible for him to live in

strict accordance with these laws; therefore if he would have his birthright, which is health, he must employ science to fit him into his artificial environment.

Man has been brought to his present state of physical development on the rural, outdoor, close-to-nature plan, and since he must live in houses and pursue occupations foreign to those through which he was developed, he must make corresponding changes in the material from which his body is constantly being repaired and made; therefore, as the selections, combinations, and proportions of the various things he needs for nourishment are determined by his age, activity, and exposure to the open air, if he accurately or even approximately ascertains and observes these things, life will continually ascend in the scale of power and grandeur, and his endurance and period of longevity will be increased.

Nearly all forms of life on this globe, except man, live approximately eight times their period of maturity. Man matures at twenty-four; measured by this scale he should live about two hundred years. But the average life of civilized man, reckoning from the age of six, is only about forty years, while if we include the infant class, and reckon the average age from his birth, he scarcely gets his growth before his hair and teeth

are disappearing, and his eyesight is being propped up by the lens of the oculist, and he quietly drops into his grave. One hundred and sixty years of life, then, is about what civilization has cost him up to date. This is very expensive, but of course he has something to show for it. He has aeroplanes, wireless communication, the mile-a-minute train, politics, several kinds of religion, rum and cocain, the tramp, the billionaire, and the bread line.

We cannot consistently leap over ten thousand years of heredity and habit, but we can recover some part of the one hundred and sixty years of life civilization has cost us. This can be done by feeding our bodies according to their requirements determined by age, temperature of environment, and work or activity; by cultivating mental tranquillity; by loving some one besides ourselves, and proving it; by breathing an abundance of fresh air, and by doing useful work. Of all these things food is the most important because it is the raw material that builds the temple wherein all other things dwell.

Civilization and science are doing but little real good for man if they cannot select for him the material necessary to develop his body and all its faculties to their highest degree, or at least free him from much of his disease and materially

increase his "ease"; they have brought him but little, I say, if they cannot show him a way to live more than forty years. Science would have nothing of which to boast if it only pointed out a way by which man could exist for two hundred years, as this is his birthright. It can only boast when it has given him more than his natural heritage.

That man's general health and period of longevity have decreased, while all other branches of science have so vastly increased, is evidence sufficient to justify the assertion that he has not employed scientific methods to the art of living, or at least to those fundamental principles, such as nutrition, motion, and oxidation, which really govern his health and his life.

The difference between youth and age, between virility and senility, is in reality a chemical difference only. The difference between the flexible cartilage of youth, and the stiff cartilage of age is one of chemistry.

If, by the process of metabolism, the muscles, bones, tissues, and brain-cells can be made to multiply and to reproduce themselves at eighteen, it seems only logical that science should give us the secret by which this same thing could be done at eighty, and if at eighty, why not at a hundred and eighty? It is by no means extravagant to

say that if science can teach us the actual demands of the body under the varied conditions of age, climate, and activity, and the means of supplying these demands with only such food elements as are needed, life can be prolonged to what seems to be our natural period of years.

Consider the human body as a machine that possesses the power of converting fuel or food into energy, using or expending that energy at will, reproducing itself piece by piece from the same fuel, and casting out the debris and ashes—if all this is done by the body automatically, and its power to act or to do these things depends so completely upon the fuel or the material with which the body has to work, then the question of the *kind* of fuel, the quantity, how to select it, how to combine it, how to proportion it, becomes at once the most important problem within the scope of human learning.

THE PURPOSE OF THIS WORK

When we compare man's longevity with other forms of life, and consider that he breathes the same air, drinks the same water, lives under the same sunshine, and that he differs from them chiefly in his habits of eating, the conviction is forced upon us that in his food is found the secret,

or the causes of most of his physical ills and his shortened life. All elements composing the human body are well known. Its daily needs are matters of common knowledge. Science has separated the human body into all its various chemical elements or parts, and weighed and named them; it has also analyzed and separated his food or fuel into its various chemical elements or parts, and named these. It would seem, therefore, a most logical step to unite these two branches of science, and to give to the world the dual science of Physio-food Chemistry, or, what I have named Applied Food Chemistry.

The sciences of physiological chemistry and of food chemistry can be made useful only by uniting them—putting them together—fitting one into the other for the betterment of the human species. These two branches of science can be of use in no other possible way except by ascertaining the demands of the human body through physiological chemistry, and by learning how to supply these demands through the science of food chemistry. In the union of these hitherto separate branches of science I can see the most useful, the most important, and the most powerful department of human knowledge. It is this union that these volumes are designed to make.

THE AUTHOR.

NEW YORK, *August, 1914.*

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A chest of miracles,
Close-packed and all secure, the unstable mass
Supported from a ruinous collapse
Or helpless flexion, by a spinous pile
Rigid as oak, yet flexile as the stem of the nodding flower.
Within, a nest of wonders, separate tasks
Each organ faithfully performing, still
From day to day harmoniously smooth
And uncomplaining, but for hindrances
Or ruinous urgence. Thou hast wisely said,
Melodious singer of old Israel,
"I am fearfully and wonderfully made."

E. C.

LESSON I

THE INTERRELATION OF FOOD CHEMISTRY AND PHYSIOLOGICAL CHEMISTRY

LESSON I

The Interrelation of Food Chemistry and Physiological Chemistry

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FOOD CHEMISTRY AND PHYSIOLOGICAL CHEMISTRY UNITED

The human body is composed of fifteen well-defined chemical elements. A normal body weighing 150 pounds contains these elements in about the following proportions:

	POUNDS	OUNCES	GRAINS
Oxygen	97	12	—
Carbon	30	—	—
Hydrogen	14	10	—
Nitrogen	2	14	—
Calcium	2	—	—
Phosphorus	1	12	190
Sulfur	—	3	270
Sodium	—	2	196
Chlorin	—	2	250
Fluorin	—	2	215
Potassium	—	—	290

Magnesium	—	—	340
Iron	—	—	180
Silicon	—	—	116
Manganese	—	—	90

There are a number of other body-elements, but they are so remote that they have not been clearly defined by physiological chemists. All these body-elements are nourished separately, or, as it were, individually. They must be replenished in the body as rapidly as they are consumed by the vital processes, and this can be accomplished only through the action of the elements, in the forms of food, air, and water, received into the body and assimilated by it.

Where 91 per cent of human ills originate

From my professional experience I have estimated that about 91 per cent of all human ills have their origin in the stomach and the intestines, and are caused directly by incorrect habits in eating and drinking. If this is true, or even approximately true, it shows that, in its relation to health and the pursuit of happiness,

food is the most important matter with which we have to deal; yet the average person devotes far less consideration to it than he does to the gossip of the neighborhood, or to the accumulating of a few surplus dollars.

Eminent writers agree as to importance of diet

Profs. Pavloff, Metchnikoff and Chittenden; Hon. R. Russell; Drs. Rabagliati, and Wiley, Ex-Chief of our Federal Bureau of Chemistry, and many other profound thinkers and writers have given in their various books an array of facts which prove beyond doubt that food is the controlling factor in life, strength, and health; yet they have given us but few practical suggestions as to how it should be selected, combined, and proportioned, so as to produce normal health, and especially how to make it remedial and curative, or to make it counteract the appalling increase in disease.

I have endeavored to begin where the great theorists left off—

1 By becoming familiar with the chemistry of food

2 By becoming familiar with the chemistry of the body

Until my work began these two great sciences had been taught as distinct and separate branches of learning, while in reality *physiological chemistry* is but half of a science, and *food chemistry* is, in fact, the other half of the same science. The energy in food cannot be developed without the body—the body cannot develop energy without food. Each branch is worthless, therefore, without the other. In this work I have endeavored to unite them and to make of the two one practical, provable, and usable science.

Food chemistry useless without body chemistry

RELATION OF SUPERACIDITY TO OTHER DISEASES

Nearly all stomach and intestinal troubles begin with superacidity. This is caused by the wrong combinations of

food, or over-eating. Food passing from the stomach, thus supercharged with acid, causes irritation of the mucous lining of the alimentary tract. This results in nervousness, insomnia, intestinal congestion (constipation), fermentation, and intestinal gas, while the excess of acid in the stomach causes irritation of the mucous surface of that much-abused organ, which develops first into catarrh, then ulceration, and sometimes into cancer. The accumulation of gas from the fermenting mass in the intestines causes irregular heart action, and sometimes heart failure. The great number of sudden deaths from this cause is pronounced by physicians "heart failure." In this the doctors and the writer agree—I know of no other way to die except for the heart to fail. The primary purpose of this work, however, is to ascertain *why* the heart fails, and, if possible, to remove the causes. From the fermenting

Superacidity a primary cause

food toxic (poisonous) substances, such as carbon dioxid, are generated, which, when taken into the circulation, become a most prolific source of autointoxication (self-poisoning).

From long experience gained by scientific feeding, in treating stomach and intestinal trouble, it became apparent that a great many disorders, very remote from the stomach, completely disappear when perfect digestion and assimilation of food, and thorough elimination of waste are effected. This has led to a very searching investigation of causes, and to the preparation of the following chart, which is designed to show how a great many so-called diseases can be traced back to one original cause—superacidity.

Aside from emotional storms, great nervous shocks, inoculation (vaccination), and violent exposure, nearly all diseases can be traced back to the stomach, or errors in eating. Even in cases of ex-

Power to resist disease depends upon correct feeding

posure, vaccination, or contagion, if the digestion and the assimilation of food, and the elimination of waste are perfect, the body will have the power to resist nearly all these causes of disease. Curing disease, therefore, by scientific feeding, is merely a method of removing causes and *giving Nature a chance* to restore normality.

Foods that ferment make inferior flesh

Food that sours, ferments, or that does not digest within Nature's time-limit, cannot make good bone and brain. A defective digestion that converts food into poisonous gases in the intestinal canal will make inferior flesh and blood, just as any other defective machine will turn out inferior work. This is the natural law governing all animal life.

Millions of learned people admit that good specimens of men and women can be constructed only out of good building material. They admit that the quality of a man, like that of a house, or a machine,

depends upon the kind of material used in his construction; and yet they allow this important material to be selected and prepared by the most ignorant and unlearned, and they take it into their bodies with a childish thoughtlessness that is amazing; and when Nature imposes her penalty for violating her laws, they seek a remedy in drugs and medicines, and these are applied only to the symptoms which are merely the protest Nature is uttering. Thus a powerful drug silences or kills the friendly messenger who brought the timely warning, but the cause still remains. Suppose houses, ships, and machinery were constructed and repaired after this plan!

Nature's protest against unsuitable building material

NATURAL LAWS DEMAND OBEDIENCE

Recompense for obedience to natural law, and punishment for its violation, are the invariable order of the universe, and are nowhere so effectively and emphati-

cally demonstrated as in the cause and cure of the condition called disease.

There are certain laws which, if obeyed, will build the human body to its highest efficiency of energy, vitality and strength; but in order to obey these laws, one must know them, and in order to know them one must pass through the long and arduous mill of experience, or else learn from one who has done so.

Pain is a warning that something is wrong with the human mechanism, and he who tries to silence this signal with medicine will be punished for two wrongs instead of one. Nature tolerates no trifling, no deception; her laws are inexorable, her penalties inevitable.

Treating symptoms instead of causes

Multitudes of people are convinced that there is *something wrong* with their eating. Instead of food giving them the highest degree of mental and physical strength, which it should do, it actually produces ills and bodily disorders; more-

over, not knowing the cause, people have no conception of a remedy other than drugs. It is amazing when one thinks how man, for two thousand years, has treated disease. Instead of studying causes and endeavoring to remove them, he has treated symptoms and symptoms only. It is generally known that the practise of medicine consists in treating symptoms rather than causes. For example, nearly all headaches—one of our common afflictions—are caused indirectly by impaired digestion, faulty secretion and excretion, yet the drug stores and Materia Medica (the Bible of the profession), are laden with "headache cures," all of which act only upon the symptoms. The whole system of drugging people when they are sick is merely a method of quieting the signals—of killing or paralyzing the messengers. Most drugs, taken into the human body, are merely diminutive explosives, the effect of which is destructive. They are like a lash

cruelly applied to a willing servant who lags from sheer exhaustion.

"Ease" and "Dis-ease"

Since symptoms are really the language of Nature, if we learn to interpret them, we need never err in diagnosis, and consequently never err in getting directly at the causes, as we must do in order to "cure." A drug that could *cure* a disorder caused by wrong feeding would perform a miracle. *It would reverse one of the fixed laws of the universe. It would produce an effect without a cause.* Nature works along the lines of least resistance, and points out with unerring certainty the best, the cheapest, and the easiest way to live. Health was originally called "ease." People who did not have health were in disgrace or "dis-eased."

HOW TO MAKE HUMAN NUTRITION A SCIENCE

Human nutrition cannot be made a science under the conventional methods of omnivorous eating—eating anything

and everything without thought or reason. Nutrition can only be made a science by limiting the articles of food to such things as will reproduce all the chemical elements of the human body, mentioned at the beginning of this lesson.

The further we remove foods from their natural state, the more difficult becomes their analysis, their reliability, and a knowledge of their chemistry, therefore the menus that appear in this work include only the foods that will give to the body the best elements of nutrition.

Prepared foods unscientific

There is but little difficulty in ascertaining the chemistry of natural foods, but when they have been preserved, pickled, canned, smoked, evaporated, milled, roasted, toasted, oiled, boiled, baked, mixed, flavored, sweetened, salted, soured and put into the popular commercial forms, it becomes very difficult, if not impossible, to know what we are eating, or to estimate the results.

Man is the net product of what he eats and drinks. Food bears very much the same relation to him that soil does to vegetation. The following questions, therefore, should be solved by every one who believes that success and happiness depend upon health and vitality:

1 How to select and how to combine foods which will give to the body a natural result, which is *health*

2 How to select and how to combine foods so that they will counteract and remove the causes of dis-ease

3 How to select foods which contain all the chemical elements of the body, and how to combine and proportion them at each meal so that they will chemically harmonize

4 How to determine the quantity of food to be taken each day, or at each meal, that will

give to the body all the nourishment it is capable of assimilating

Note: Too much food, even of the right kind, defeats this purpose and produces just the opposite result.

Upon this knowledge hinges the building of a natural body, the cure of a vast majority of dis-eases, our ability to reach the highest state of physical and mental vitality, the prolongation of youth and longevity.

OUR FOOD MUST FIT INTO OUR CIVILIZATION

We must make our diet fit into our civilized requirements. Civilization has imposed many customs, habits, and duties upon us that have not been properly met by nutrition or diet. This is why nearly 91 per cent of our ills are caused by errors in eating.

Effect of sedative occupations upon nutrition

Under continued physical exertion, the body will thrive for a time on an unbalanced diet. It will cast off surplus nutrition, and convert one element into another, a problem unknown to modern science, but under sedative or modern business habits and occupations, it will not continue to cast off a surplus, or to reconvert nutritive elements. As a result of an unbalanced bill of fare, the nutrients taken in excess of the daily needs undergo a form of decomposition, producing what is called autointoxication, and become a most prolific source of dis-ease.

WHY THE SCIENCE OF HUMAN NUTRITION IS IN ITS INFANCY

The reader may inquire why it is that all other branches of science have advanced so rapidly, and the science of human nutrition has just begun. The reasons are:

1 Our ancestors, for many thousand years, were taught that dis-ease was a visitation of Divine Providence, therefore to combat it was to tempt the Almighty.

2 Doctors of medicine who have been custodians of the people's health for many centuries have seldom been food scientists. Most of them attempt to combat disease with drugs.

Now we are beginning to learn the truth about the origin of disease and in considering the body as a human engine, to take into consideration the all-important question of fuel.

Tendency of the modern physician toward food science

That the most learned physicians are drifting more and more toward scientific feeding and natural remedies is a matter of common knowledge. This splendid army of laborers in the great field of human suffering is made up largely

of what is termed the *Modern Doctor*—the man who is brave enough to think and to act according to his better judgment.

Just to the extent that we understand the origin of drugs, and the drugging system of treating dis-ease, we turn instinctively *from them*, and instinctively *toward* food, for in drugs we find an ancient system of guesswork, while in food we find fundamental principles and primary causes. The majority of causes are removed when the diet is made to fit our physical condition and environment, and we then become normal by the process of animal evolution, Nature merely bestowing upon us our birthright because we have obeyed her laws.

3 The true science of human nutrition can be evolved only from an accurate knowledge of both food chemistry and of physiological chemistry.

The science of physiological chemistry has been known and taught for more than one hundred years, while the science of food chemistry is of recent origin. These two branches have been kept separate because they grew up at different periods of time. United they constitute the greatest science known to mankind, because they affect his health, his happiness, his life, and above all they measure the period of time he will live.

Why food chemistry and physiological chemistry have not been united

Physiological chemistry tells what the body is and its needs—food chemistry tells how to supply these needs. Recognizing these facts, I have merely united these hitherto unapplied branches of science, and have made of the union the science of Applied Food Chemistry, which makes practical that which has heretofore been confined mainly to theory.

LESSON II

SIMPLE PRINCIPLES OF GENERAL CHEMISTRY

LESSON II

Simple Principles of General Chemistry

If the student is versed in chemistry, this lesson will serve merely as a review; if not, somewhat close attention must be given to facts which at first may seem uninteresting. Patience should be exercised, for, while all the information herein given does not, taken as a whole, bear directly upon the subjects of health and dis-ease, yet with this knowledge it will be much less difficult to understand the principles which are applied later when we take up the chemistry of the body and the chemistry of food.

Relation of chemistry to food science

Chemistry is not, as popularly supposed, a science far removed from everyday life. Everyone has some knowledge

of chemistry, but the chemist has observed things more minutely and therefore more accurately understands the composition of substances and the changes that are everywhere taking place. For illustration:

> A cook starts a fire in a stove. She knows that the fire must have "air" or it will not burn; that when the fire is first lighted, it "smokes" heavily, but as it burns more, it smokes less; further, that if the damper in the pipe is closed the "gas" will escape in to the room.

Fire, gas, and smoke the result of chemical changes

The chemist also knows this, but because he has compared his observations with similar events elsewhere, he is enabled to express his knowledge in the language of science. To the chemist, fire is the process of combustion—the union of the oxygen of the air with the carbon and hydrogen compounds of the wood or of the coal. The heat of the fire is generated by this chemical union. To

the chemist, the smoke is a natural phenomenon occasioned by particles of carbon which fail to unite with the oxygen gas. The gas, which to the woman suggests suffocation if enough of it escapes into the room, to the chemist suggests a compound resulting from combination of the oxygen with the carbon.

CHEMICAL ELEMENTS

To the chemist, all forms of matter are mere combinations of elements. Chemical analysis is a process of separating, dividing, and subdividing matter. When the chemist separates or analyzes compounds, until he can no longer simplify or subdivide them, he calls these simple products "chemical elements."

Common elements

Many of the chemical elements are well known, such as copper, iron, and gold. Other elements that are still more common are unknown in their elementary form, because they combine with

other elements so readily that they exist in nature only as compounds. For example: Hydrogen, united with oxygen, forms water; the elements chlorin and sodium, combined or united, form common salt.

Number of elements

Altogether chemists have discovered about eighty-four elements, many of which are rare, and do not occur in common substances.

All substances of the earth, whether dead or living, are formed of chemical elements. These elements may be found in the pure or elementary state, or they may be mixed with other substances, or they may be combined chemically. Copper, iron, and gold are elements in the pure state. If we should take iron and copper filings and mix them together, we would still have copper and iron. Were we to take copper and gold and melt them together, we would have a metal that would be neither copper nor gold.

It would be harder than one and softer than the other. But this substance would still be a mixture, and its properties half way between copper and gold.

If a piece of iron be exposed to dampness it will soon become covered with a reddish powder called "rust." The rusting of iron is a process of chemical changes in which the original substance was wholly changed by chemically uniting with the oxygen and the moisture of the atmosphere, which is really a process of combustion. The burning of wood, the rusting of iron, the souring of milk, and the digestion of food are, in a way, all mere examples of chemical changes.

Examples of chemical changes

Care should be exercised to distinguish chemical compounds from simple mixtures. Air is not a compound, but a mixture of oxygen, hydrogen and nitrogen gases. Water, however, is a compound of oxygen and hydrogen. Both salt and

Difference between chemical compounds and simple mixtures

sugar are compounds, but if we grind them together, we do not have a new compound, but a mixture of two compounds. Most of the common things around us are mixtures of different compounds or substances. Rocks are mixtures of many different compounds. Wood is, likewise, formed of many different substances. Wheat contains water, starch, cellulose, and many other compounds. Grinding the wheat into flour does not change it chemically, but if we heat the flour in an oven, some of the starch is changed into dextrin. The starch has disappeared, and dextrin, a new substance, appears in its place. Whenever elements are combined into compounds, or compounds broken up into elements, or changed into other compounds, we have true chemical action.

The names of the elements are formed in many different ways. The name chlorin is derived from a Greek word meaning *greenish-yellow*, as this is the color of chlorin. Bromin comes from a Greek

word meaning *a stench*, a prominent characteristic of bromin being its bad odor.

Names of elements—how derived

Hydrogen is formed from two Greek words, one of which means *water* and the other *to produce*, signifying that it enters into the composition of water. Potassium is an element found in potash, and sodium in soda, etc.

For convenience, abbreviations are used for the names of elements and compounds.

Symbols of elements—how derived

Thus, instead of oxygen, we may write simply "O"; for hydrogen, "H"; for nitrogen, "N," etc. Very frequently the first letter of the name of the element is used as the symbol. If the names of two or more elements begin with the same letter, some other letter of the name is added. In some cases the symbols are derived from the Latin names of the elements. Thus, the symbol of iron is Fe, from *ferrum;* of copper, Cu, from *cuprum.*

The following table gives the names of the elements which it will be necessary to understand in pursuing this work.

Aluminum	Al	Gold	Au	Phosphorus	P
Arsenic	As	Hydrogen	H	Platinum	Pt
Boron	B	Iodin	I	Potassium	K
Bromin	Br	Iron	Fe	Silicon	Si
Calcium	Ca	Lead	Pb	Silver	Ag
Carbon	C	Magnesium	Mg	Sodium	Na
Chlorin	Cl	Mercury	Hg	Sulfur	S
Chromium	Cr	Nickel	Ni	Tin	Sn
Copper	Cu	Nitrogen	N	Zinc	Zn
Fluorin	F	Oxygen	O		

AIR AND OXYGEN

Composition of air

AIR—The air consists chiefly of two substances, only one of which can keep up the process of burning. This substance is known as oxygen. The other, in which nothing can burn, is known as nitrogen. Besides these the air contains smaller quantities of other substances, particularly water vapor, carbonic acid (carbon dioxid), ammonia, and carburetted hydrogen.

Distribution of oxygen

OXYGEN—Oxygen is the most common element in nature. It forms between forty and fifty per cent of the solid crust of the earth, eight-ninths of all the water on the globe, and one-fifth of all the air around the globe.

We have oxygen around us in great abundance, but it is mixed with nitrogen, and it is difficult to separate the two so as to secure the oxygen for any practical or commercial use.

MANUFACTURE OF OXYGEN

There are three methods of obtaining oxygen:

1 From *potassium chlorate*, or, as it is commonly called, chlorate of potash.

When potassium chlorate ($KCLO_3$) is heated in a closed ves-

sel (closed vessel means "closed at one end"), it breaks up into potassium chlorid and oxygen; that is, $KCLO_3$ + heat = $KCL + O_3$.

Potassium chlorate is used in fireworks because it gives up its oxygen readily. Potassium nitrate serves the same purpose in gunpowder, which is a mixture of sulfur (S), charcoal (C), and saltpeter or potassium nitrate (KNO_3). The explosion of gunpowder, after a certain temperature has been reached, is due to the formation of oxygen, which, combined with the potassium nitrate, is set free by the very rapid burning of the charcoal and the sulfur. Other gases formed by the explosion are nitrogen, and probably sulfur dioxid (SO_2), and oxids of nitrogen, N_2O, NO_2, etc. Carbon monoxid and carbon dioxid are sometimes formed. Potassium nitrate, however, is the most active agent in gunpowder.

2 By the *electrolysis of water.*

By this method the oxygen and the hydrogen are separated by electricity.

3 By the *liquefaction of air,* which is a very recent and a very scientific method.

By this method the air is cooled down until it liquefies. At normal atmospheric pressure it liquefies at a temperature of —312.6°F., but under pressure of about 585 pounds it liquefies at a temperature of —220°F. After the air has been liquefied, it is allowed to go back to vapor by exposing it to the surrounding heat of the atmosphere, and this vaporization separates the nitrogen from the oxygen, as the nitrogen boils at a temperature of —318°F., while the oxygen boils at a temperature of —294°F. There is a difference of about 24° in the boiling points of these two

gases, which at this low point amounts to more than the difference between the boiling points of alcohol and water, and this difference is sufficient to separate the oxygen from the nitrogen.

Production of oxygen by the liquefaction of air is the latest, cheapest, and most approved method, and is now becoming extensively used in obtaining both oxygen and nitrogen for commercial use.

Properties of oxygen

Oxygen is tasteless and odorless. It is slightly heavier than air. When subjected to an extremely high pressure and low temperature it becomes liquid.

CHEMICAL ACTION OF OXYGEN

(a) *Upon Substances*

Upon some substances oxygen acts at ordinary temperature. Iron becomes

Effect of air upon iron and wood

covered with rust when exposed to air and moisture. Wood and other vegetable and animal substances undergo slow decomposition when exposed to the air. This is partly due to the action of oxygen at ordinary temperature.

A splinter of wood will burn brilliantly in a jar of pure oxygen, and much more rapidly than in common air. Pure oxygen gas will cause many substances to burn which will not burn in air. Iron can be burned in pure oxygen, leaving only a reddish powder.

Pure oxygen aids combustion

When iron rusts the carbon dioxid and water vapor combine chemically with the iron, and form what is known as a basic hydroxid or carbonate of iron. The process is somewhat complex. When iron burns in oxygen a red powder is formed—ferric oxid, Fe_2O_3. Iron dissolves in water, or moisture from the air contain-

Formation of iron-rust

ing carbonic acid, forming acid ferrous carbonate—

$$\begin{array}{llll} Fe & +\ 2H_2CO_3 & = FeH_2(CO_3)_2 & +\ H_2 \\ \text{Iron} & +\ \text{Carbonic acid} & = \begin{array}{c}\text{Acid ferrous}\\ \text{carbonate}\end{array} & +\ \text{Hydrogen} \end{array}$$

This acid ferrous carbonate, on drying or further oxidation, is converted into *iron-rust.* If we represent *iron-rust* by the formula $Fe_2O_3.\ 2Fe(OH)_3$, the equation is as follows:

$$\begin{array}{llllll} 4FeH_2(CO_3)_2 & +\ O_2 & = Fe_2O_3.\ 2Fe(OH)_3 & +\ H_2O & +\ 8CO_2 \\ \begin{array}{c}\text{Acid ferrous}\\ \text{carbonate}\end{array} & +\ \text{Oxygen} & = \text{Iron-rust} & +\ \text{Water} & +\ \begin{array}{c}\text{Carbon}\\ \text{dioxid}\end{array} \end{array}$$

(b) *In Living Bodies*

The most interesting action of oxygen at ordinary temperature, however, is that which takes place in our bodies and the bodies of all other animals.

By the constant action or beating of the heart all the blood in the body is brought to the lungs every two or three

minutes. The actual time has not been determined in man. In large arteries the blood flows ten times as fast as in very small ones. The usual time through a capillary is one second. The time has been determined, however, in lower animals. In a horse the blood travels one foot a second in the largest artery. At present the accepted theory is that in the circuit the blood makes throughout the body, it picks up the waste matter from tissue that has been torn down by work or effort, and brings it to the lungs, where it meets with the oxygen we breathe and is oxidized or burned.

Rate of blood circulation

Oxidation of waste matter

If the body undergoes excessive effort or exercise, it tears down an excessive amount of tissue, and there is created, therefore, an excessive amount of waste or carbon dioxid. Nature very wisely provides for this contingency by increasing the heart action, thereby sending the

blood through the body at greater velocity, forcing more blood to the lungs, thus increasing the demand for oxygen, which is expressed by deep and rapid breathing.

Generation of heat and light

When a substance burns it gives off heat, and generally light. The heat is the result of chemical change or combination, and the light is the result of heat. Whenever oxidation takes place, no matter in what form, heat is produced.

Amount of heat determined by amount of oxygen

The amount of heat given off by the combination of a given amount of oxygen with some other substance is always the same. If it takes place at a very high temperature, as in explosives, the heat is all given off at once, but if it takes place more slowly, the heat passes away, and we may not observe it, but careful experiments prove that heat is always present in oxidation, and the amount of heat is always measured by the amount of oxygen.

That the combination of oxygen with other substances always produces a certain amount of heat is a very important fact to the food scientist, as this law enables him to determine in the laboratory the exact amount of heat that is produced in the oxidation of a pound, or of any given quantity of food; this food will also produce exactly the same amount of heat if oxidized in the human body.

Law governing oxidation of given quantity of food

We know that by means of heat we can produce motion. The steam-engine is the best example of this law. We build a fire under the boiler; the oxygen of the air unites with the carbon in the coal; the combustion converts the water into steam; the steam is conveyed to a cylinder; the pressure pushes a piston; the motion of the piston causes motion in the engine, and the train or ship moves.

Heat and motion

From such facts we know that not only the amount of heat, but the amount of work or energy that food or fuel will yield can be determined with reasonable accuracy. Many conditions obtain in the body, however, that do not occur in the laboratory, hence we must study these conditions before we can fully understand the natural laws that govern the production of heat, and energy or work, by oxidation in the living body.

Determination of body-heat and energy

HYDROGEN AND WATER

HYDROGEN—Hydrogen is found in nature very widely distributed and in large quantities. It forms one-ninth of the weight of water, and is contained in all the principal substances which enter into the composition of plants and animals. It may be obtained by decomposition of

Distribution and production of hydrogen

water by means of the electric current, or by the action of substances known as acids on metals. The latter method is more commonly used in the laboratory. Acids contain hydrogen, give it off easily, and take up other elements in its place. Among the common acids found in every laboratory are hydrochloric, sulfuric, and nitric.

Physical properties of hydrogen

Pure hydrogen is a colorless, odorless, tasteless gas. It is not poisonous, and may therefore be inhaled without harm. It is the lightest known substance, being about 14.4 times lighter than air, 16 times lighter than oxygen, and 11,000 times lighter than water.

Chemical properties of hydrogen

Hydrogen does not unite with oxygen at ordinary temperatures, but, like wood and most other fuel substances, needs to be heated up to the kindling temperature before it will burn. Hydrogen burns if a lighted match be applied

to it. The flame is colorless, or very slightly blue.

WATER—Water is a compound and not an element, as can be shown by passing an electric current through it. If the ends of two wires, each connected with an electric battery, be put a short distance apart, in acidulated water, it will be noticed that bubbles of gas rise from each wire. As these gases cannot come from, or through the wires, they must be formed from the water. If they be analyzed, we will find that oxygen gas comes from one wire and hydrogen from the other.

Decomposition of water

This experiment shows that when an electric current is passed through water, hydrogen and oxygen are obtained, and also that there is obtained twice as much hydrogen as oxygen by volume. This proves that water is not an element,

Proportion of hydrogen and oxygen in water

but a compound of two atoms of hydrogen and one of oxygen. The chemist therefore writes the symbol for water H_2O.

We have just learned that with electricity we could decompose the compound water into its elements, hydrogen and oxygen. Now we can prove by another experiment that water contains these two elements. If we burn hydrogen gas, or any substance containing hydrogen, water is formed. This can be illustrated by inverting a cool, dry tumbler over a gas flame, which is composed chiefly of hydrogen, and water vapor will collect on the inside.

Properties of water

Though water is widely distributed over the earth, we never find it absolutely pure in nature. All natural waters contain foreign substances in solution. These substances are taken up from the air, or from the earth. Pure water is colorless, tasteless, and odorless.

On cooling, water contracts until it reaches the temperature of 4° Centigrade (39° Fahrenheit). When cooled from 4° to 0° C. it expands, and the specific gravity, or weight compared with the space occupied by ice, is somewhat less than that of water; hence ice floats.

Why ice floats

The purest water found in nature is rain-water, particularly that which falls after it has rained for some time; that which first falls always contains impurities from the air. As soon as rain-water comes in contact with the earth and begins its course toward the sea, it also begins to take up various substances according to the character of the soil with which it comes in contact. Mountain streams which flow over rocky beds, particularly beds of sandstone, contain very pure water.

Rain-water

Streams which flow over limestone dissolve some of the stone, and the water becomes "hard."

Hard water

Mineral water

The many varieties of mineral water from the various springs throughout the country, take their properties from soluble substances with which they come in contact.

Salt water

Common salt is deposited in large quantities in different parts of the earth. Since salt is readily soluble in water, many streams pick up large quantities of it, and as all water courses ultimately find their way to the ocean, the latter becomes a repository for salt with which the earth-water is laden.

Effervescent waters

Effervescent waters all contain some gas, usually carbonic acid gas in solution, and they merely give up or set free a part of it when placed in open vessels.

Sulfur water

Sulfur water contains a compound of hydrogen and sulfur, called hydrogen sulfid or sulfureted hydrogen, which we will refer to in its order later in this lesson.

Water may be purified by means of distillation. This consists in boiling the water and condensing the vapor by passing it through a tube which is kept cool by surrounding it with cold water. By means of distillation most substances in solution in water can be eliminated. Substances, however, which evaporate like water, will, of course, pass off with the water vapor. Aboard ship salt water is distilled and thus made fit for drinking. In chemical laboratories ordinary water is distilled in order to purify it for chemical work.

Distilled water

USES OF WATER IN CHEMISTRY

Water is termed by the chemist a stable compound. This means that it is difficult to get it to act chemically. Being thus inactive chemically, we find that water does not combine with most sub-

Action of water in physiological chemistry

stances. There are exceptions to this, however, especially in physiological chemistry, an instance being that starch combines with water when it is changed to sugar in the process of digestion.

Water as a solvent

Water is the universal solvent. A greater number of substances dissolve in it than in any other liquid. Chemical operations are frequently carried on in solution, that is to say, the substances which are to act chemically upon each other are first dissolved in water. The object of this is to get the substances into as close contact as possible. If we rub two solids together, the particles remain slightly separated, no matter how finely the mixture may be powdered. If, however, the substances are dissolved and the solutions poured together, the particles of the liquid move so freely among each other that they come in direct contact, thus aiding chemical action. In some cases substances which do not act on each

other at all when brought together in dry condition, act readily when brought together in solution.

There is a limit to the amount of any substance which can be held in solution at a given temperature.

The question will probably arise in the mind of the student as to whether a substance dissolved in water has chemically united with the water, or is merely mixed.

Chemical meaning of solution

Solution is in reality a process about half way between mixing dry substances and forming chemical combinations. The chemist considers that the water does not form a compound with the substance dissolved, when he can, by evaporating the water, get the substance back into its original form.

IMPORTANCE OF SOLUTION TO THE FOOD SCIENTIST

Solution is very important in the study of foods and human nutrition. Only

substances which can be dissolved can be assimilated. Many substances which will not dissolve in pure water will dissolve in water which contains something else in solution. The blood is water containing many things in solution. The salts of the blood keep the other food elements in solution, many of which would not dissolve if the blood did not contain these salts. The chief work of the digestive juices is to reduce foods to a soluble form so that they can be taken into the circulation by absorption; otherwise they would pass through the alimentary canal practically unchanged.

Relation of solution to assimilation

We must learn to distinguish carefully between chemical solution and merely mixing things with water. A good example is milk. In addition to water, milk contains principally fat, sugar, and casein. The sugar is truly dissolved in the water. The fat and the casein are fine particles

Milk as an example of both "Solution" and "Mixture"

held in suspension. If the milk stands for a while, the fat particles rise to the top as cream. If it stands long enough, the casein particles adhere to each other and settle to the bottom, leaving the water with the dissolved sugar or whey in the middle.

IMPORTANCE OF WATER IN THE HUMAN BODY

Proportion of water and solids in the human body

Water, which forms about sixty-six per cent of the human body, is by far the most important substance therein. It comprises the major part of the blood serum and every tissue and organ. If a normal human body weighing 150 pounds were put into an oven and thoroughly dried, there would be left only about 50 pounds of solid matter, all the rest being water. The proportion of water in animal and vegetable substances is also very great. As water is also a conspicuous factor in all foods, either in chemical

combination, or in solution with other elements mechanically mixed, it is obvious that water is an important factor in food science.

USES OF WATER IN THE BODY

The uses of water in the body may be roughly grouped into three divisions, as follows:

1 Water in small quantities enters into the actual chemical composition of the body.

As we will notice in the discussion of carbohydrates, water combines chemically with cane-sugar when it is digested and transformed into glucose. (See Lesson IV, "Cane-sugar," page 112.)

2 Water forms a portion of the tissues and acts as a solvent in the body-fluids.

In this function the water is not changed chemically, but is only mixed with other substances; thus the blood is in reality water with glucose, peptone, etc., in solution, and carrying along with them red blood-corpuscles and fatty globules.

What blood carries in solution

3 Water is a most important factor in the digestion, and the assimilation of food, and the elimination of waste.

Inasmuch as the body is nearly two-thirds water, it follows that the diet should be composed of about 66 per cent moisture. The old theory of dietitians that no water should be taken with meals was based upon the hypothesis that the water diluted the gastric juice, and that this diluted form of the gastric juice weakened its digestive power. Actual practise

Drinking with meals

has proved this thesis to be untrue. Water is the great universal solvent, and the hydrochloric acid of the stomach is only a helper, as it were, in the dissolution or the preparation of food for digestion.

Water is also a valuable agent in the elimination of body-poisons.

Value of water to blood

The liberal use of water keeps the blood supplied with the necessary moisture, and that excess which is eliminated through the kidneys carries away poisons that would reside in the body very much to the detriment of health. There is little danger, therefore, in drinking too much pure water, but much care should be exercised that it be pure, or at least free from lime and mineral deposits. The best water is pure water, free from all mineral substances.

If a meal consists of watery food, such as fresh vegetables, salads, etc., then the drinking of water becomes unnecessary;

but where the meal is composed chiefly of solids, then an amount of water should be taken sufficient to make up 66 per cent of the total. If more water is taken than is necessary for this purpose, the excess will pass off and the stomach will only retain the necessary amount; but if the quantity of moisture is insufficient, the stomach calls to its aid an excess of hydrochloric acid, the strength of which has a tendency to crystallize the starch atom (especially cereal starch), thereby causing the blood-crystal, which is one of the primary causes of rheumatism, gout, lumbago, arterial sclerosis (hardening of the arteries), and all disorders caused by congestion throughout the capillary and the arterial systems. The most common disorder among civilized people is hydrochloric acid fermentation. Copious water drinking at meals is the logical remedy for this disorder.

When water drinking is unnecessary

Disorders caused by insufficient moisture

The proper amount of pure non-mineral water taken with food will do much to remove the causes of superacidity and the long train of ills that follow this disorder. (See "Chart," Lesson I, page 9.)

In this work I shall constantly refer to these various uses of water, especially as a solvent (an aid to digestion), and as a remedial and curative agent.

Man's source of water

Theories have been promulgated by hygienic teachers in the past few years that man should get his supply of water wholly from the juices of fruits, and not drink ground-waters, which are contaminated with mineral substances. While it may be true that water in certain localities, such as in the alkali deserts, is unfit for drinking, yet the writer believes that the promulgators of the theory that man is not a drinking animal never did a hard day's work in a harvest field. In the dry winds of the western plains water evaporates from the surface of the

body at the rate of twelve or fifteen pounds a day. The theory of deriving one's water supply wholly from fruits would not stand the test of such facts.

NITROGEN AND NITROGEN COMPOUNDS

Sources of nitrogen

We have learned that the air is composed chiefly of oxygen and nitrogen. These are not combined as oxygen and hydrogen are in water, but are simply mixed together, four-fifths of the mixture being nitrogen. Nitrogen is also found in combination in a large number of substances in nature. It is found in the nitrates, as saltpeter or potassium nitrate, KNO_3, and Chili saltpeter or sodium nitrate, $NaNO_3$. It is also found in the form of ammonia, which is a compound of nitrogen and hydrogen of the formula NH_3, and exists in that form in a limited quantity of the air. In most foods, especially in those of animal origin, nitrogen occurs in chemical combination.

Properties of nitrogen

Nitrogen is a colorless, tasteless, odorless gas which does not burn, and does not combine readily with oxygen, or with any other element except at a very high temperature, and except in the formation of living plants, or in animal life. Just as nitrogen does not support combustion, so also it does not support life. An animal would die confined in a tank of nitrogen, not on account of any active poisonous properties in the nitrogen, but for lack of oxygen.

Compounds of nitrogen

When a compound containing carbon, hydrogen and nitrogen is heated in a closed vessel, so that the air is excluded, and so that it cannot burn, the nitrogen passes out of the compound, not as nitrogen, but in combination with hydrogen, which forms ammonia. Nearly all animal substances contain carbon, hydrogen, oxygen, and nitrogen, and many of them

give off ammonia when heated as above described.

Ammonia is written by the chemist NH_3, or one part of nitrogen gas to three parts of hydrogen. It is a colorless, transparent gas with a very penetrating, characteristic odor. In concentrated form it causes suffocation. It is but little more than half as heavy as air. It is easily converted into liquid form by pressure and cold. When pressure is removed from the liquefied ammonia, it passes back very rapidly into gaseous form, and in so doing it absorbs heat. Investigators have taken advantage of these facts and are employing liquid ammonia in the manufacture of artificial ice.

Why ammonia is used in making artificial ice

While air is merely a mixture of oxygen and nitrogen, this does not prove that these two elements cannot unite. In fact they do unite in five different proportions so as to form five different substances.

These are given below to illustrate how different substances can be formed from the same things, by merely combining them in different proportions. This example is also given to impress upon the mind of the practitioner the great importance of proportioning nutritive elements in diet so that the patient will not be overfed on some elements while underfed on others. It is absolutely essential, in order to know what effect a substance will have in the laboratory, or in the body, to know not only of what it is composed, but with what substances and in what proportions it is combined.

Importance of proportioning food

Nitrous oxid	N_2O
Nitric oxid	NO or N_2O_2
Nitrogen trioxid ..	N_2O_3
Nitrogen peroxid ..	NO_2 or N_2O_4
Nitrogen pentoxid	N_2O_5

To further illustrate the wonders of chemical combinations, we give the prop-

erties of two of these oxygen and nitrogen compounds:

Properties and uses of nitrous oxid

Nitrous oxid, N_2O, is colorless, transparent, and has a slightly sweetish taste. When inhaled it causes a kind of intoxication which manifests itself in the form of hysterical laughing, hence it is commonly called "laughing gas." Inhaled in larger quantities it causes unconsciousness and insensibility to pain. It is, therefore, used in many surgical operations, particularly by dentists in extracting teeth.

Nitrogen peroxid, NO_2, is a reddish-brown gas. It has an extremely disagreeable odor and is very poisonous.

Composition of nitric acid

By oxidation the nitrogen of animal substances is converted into nitric acid, HNO_3. Furthermore, the silent, continuous action of minute living organisms in the cell is always tending to transform the waste-products of animal life into compounds closely related to nitric acid.

This acid, as its chemical formula indicates, is formed by the combination of the three elements we have just studied, namely, hydrogen, nitrogen, and oxygen. Pure nitric acid is a colorless liquid. It gives off colorless, irritating fumes, when exposed to the air. Strong nitric acid acts violently upon many substances, particularly those of animal and vegetable origin, decomposing them very rapidly. Nitric acid burns the flesh, eats through clothing, disintegrates wood, and dissolves metals. It is one of the most active of chemical substances.

Properties of nitric acid

The compounds of nitrogen that occur in food are very numerous and of complex composition. They will be discussed in Lessons III and IV, pages 99 and 125 respectively.

CHLORIN

Chlorin, though widely distributed in nature, does not occur in very large

quantities as compared with oxygen and hydrogen. It is found chiefly in combination with the element sodium, as common salt or sodium chlorid, which is represented by the symbol NaCL.

Sources of chlorin

Chlorin is a greenish-yellow gas. It has a disagreeable smell and acts upon the passages of the throat and nose, causing irritation and inflammation. The feeling produced is much like that of a cold in the head. Inhaled in concentrated form, that is, not diluted with a great deal of air, it would cause death. It is much heavier than air, combines readily with other substances, and possesses the property of bleaching or destroying colors.

Properties of chlorin

HYDROCHLORIC ACID

Just as hydrogen burns in the air, so it burns in chlorin. The burning of hydrogen in air or oxygen is, as we have seen, simply the combination of hydrogen and

oxygen, the product being water in the form of vapor, and therefore invisible.

Hydrogen and chlorin combined

When hydrogen burns in chlorin, the action consists in the union of the two gases, the product being hydrochloric acid, HCl, which forms clouds in the air. The two gases, hydrogen and chlorin, may be mixed together and allowed to stand together indefinitely in the dark, and no action will take place. If, however, the mixture be put into a room lighted by the sun, but where the sun does not shine directly upon it, combination takes place gradually; but if the sun be allowed to shine directly upon the mixture for an instant, explosion occurs, this being the result of the combination of the two gases. The same result can be caused by applying a flame or spark to the mixture. In this case light causes chemical action. The art of photography depends upon the fact that light has the power to cause chemical changes.

Importance and preparation of hydrochloric acid

I will here consider hydrochloric acid somewhat in detail, because it is very important in the digestion of food, being the principal fluid composing the gastric juice of the stomach. Hydrochloric acid is always made by treating common salt (one afflicted with acid fermentation should omit the use of salt and soda), under high temperature, with sulfuric acid. This product is given off as a gas, which dissolved in water forms hydrochloric acid, sodium sulfate remaining behind as a result of this process. The chemist describes the action that takes place by writing what is called a chemical equation, as follows:

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$$

$$\begin{array}{c} \text{Sodium chlorid} \\ \text{(common salt)} \end{array} + \begin{array}{c} \text{Sulphuric} \\ \text{acid} \end{array} = \begin{array}{c} \text{Sodium} \\ \text{Sulfate} \end{array} + \begin{array}{c} \text{Hydrochloric} \\ \text{acid} \end{array}$$

The reader will observe that there are as many parts of each element on the

right as on the left-hand side of the = mark. Two parts of common salt yield two parts each of sodium (Na) and chlorin (Cl). The sodium appears as *Na* in the sodium sulfate, and the chlorin as *Cl* in the two parts of hydrochloric acid.

This method of expressing chemical action by these equations may be somewhat confusing at first to those who have not studied chemistry, but it is best to have all such become familiar with them that they may have the further benefit of understanding the general terms of chemistry.

Hydrochloric acid gives up its hydrogen when brought into contact with certain metals like iron, zinc, etc., and takes up these metallic elements in place of the hydrogen. Thus zinc and hydrochloric acid give zinc chlorid and hydrogen.

Zn	+	$2HCL$	=	$ZnCl_2$	+	H_2
Zinc	+	Hydrochloric acid	=	Zinc chlorid	+	Hydrogen

ACIDS, BASES, NEUTRALIZATION, SALTS

We have already discussed a number of substances called acids. It is necessary to inquire why chemists call them acids. What is there in common, for example, between the heavy, oily liquid sulfuric acid and the colorless gas, hydrochloric acid? It is not possible to understand the nature of their common properties without examining a class of substances called alkalis or bases.

Relation of acids to bases

Acids and bases have the power to destroy the characteristic properties of each other. When an acid is brought into contact with a base, in proper proportions, the characteristic properties of both the acid and the base are destroyed. They are said to neutralize each other.

The most common acids are sulfuric, hydrochloric, and nitric. Among the more common bases are caustic soda, caustic potash, and lime. A convenient

way to recognize whether a substance has acid or basic properties is by means of certain color-changes. Litmus is a coloring matter which is ordinarily blue. If a solution which is colored blue with litmus be treated with a drop or two of an acid, the color is changed to red. If the red solution be treated with a few drops of a solution of a base, the blue color is restored.

Common acids and bases and tests therefor

Many substances change in color according to whether the solutions in which they are present are acid or alkaline. An infusion of red cabbage, for example, changes color when treated with an acid, and recovers its color when again treated with an alkali.

What happens in the chemical sense in this neutralizing process is nicely illustrated by the formation of common salt from hydrochloric acid and caustic soda, also called sodium hydroxid. When these

Formation of common salt

two substances are dissolved in water, and the solutions mixed, the chemical action is as follows:

HCL	+	NaOH	=	H_2O	+	NaCl
Hydrochloric acid (Muriatic acid)	+	Caustic soda (Sodium hydroxid)	=	Water	+	Common salt (Sodium chloride)

Common examples of neutralization

The strong hydrochloric acid with its pungent odor and sour taste, and the caustic alkali with its equally characteristic properties have both disappeared, and in their place we find nothing more wonderful than common salt dissolved in water. Other forms of neutralization that are very common are vinegar (acetic acid $C_2H_4O_2$) and soda, or sour milk (lactic acid $C_3H_6O_3$) and soda. When bread is "sour," we mean that there was not enough soda to neutralize the acid.

PRINCIPLES OF NEUTRALIZING ALKALIS

If we should try many experiments of neutralizing alkalis with acids, we would discover these general rules:

1 All acids contain hydrogen.

2 All alkalis contain oxygen and hydrogen in equal proportions.

3 When these substances react, the hydrogen of the acid joins the hydrogen of the base or alkali, forming water, H_2O.

4 The metal of the base always replaces the hydrogen of the acid.

$2KOH$	$+$	H_2SO_4	$=$	K_2SO_4	$+$	$2H_2O$
Potassium		Sulfuric		Potassium		
hydroxid	+	acid	=	Sulfate	+	Water
(alkali or base)		(acid)		(Salt)		

(In the above equation the potassium (K) of the potassium hydroxid replaces the Hydrogen (H) in the sulfuric acid.)

5 The other elements of the original compounds unite to form a new substance, which is neither acid nor alkali, but which is termed a salt.

The names of a few common acids, bases and salts, and their chemical formulas, are given here, as many of them will be important in the pursuance of this work.

ACIDS

HCl ......Hydrochloric (in gastric juice)
HNO_3 .....Nitric
H_2SO_4 ....Sulfuric
$C_2H_4O_2$ ...Acetic (vinegar)
$C_6H_8O_7$ ...Citric (lemon juice)

BASES

$NaOH$ ....Sodium hydroxid (caustic soda)
KOH .....Potassium hydroxid (caustic potash)
$Ca(OH)_2$...Calcium hydroxid (slaked lime)
NH_4OH ...Ammonium hydroxid
(Ammonia gas dissolved in water produces this alkali.) The equation for this is as follows:

$$\underset{\text{(Ammonia) gas}}{NH_3} + \underset{\text{Water}}{H_2O} + \underset{\text{Ammonium hydroxid}}{NH_4OH}$$

SALTS

$NaCl$	Sodium chlorid (table salt)
KNO_3	Potassium nitrate (salt-peter)
$CuSO_4$	Copper sulfate (blue vitriol)
$Ca_3(PO_4)_2$.	Calcium phosphate (normal) (The mineral of bones)

FLUORIN, BROMIN, IODIN—These three elements are in many respects like chlorin. The first is a gas, the second a heavy, reddish-brown liquid at ordinary temperature, and the third a dark, grayish crystalline solid. These elements all form acids just as chlorin forms hydrochloric acid. These acids produce salts, and these various salts exist in small quantities in the human body.

Formation of salts in the human body

MINERAL SULFUR—This element is of no particular importance or use to the body, as it is insoluble and cannot be digested. The compounds of sulfur, however, are numerous and important. Sulfuric acid, sometimes called oil of vitriol, is one of the most active chemi-

cals known, and is especially destructive to living tissue, as it combines with the water in the tissue so rapidly as to char or burn it.

When sulfur is burned in air it forms sulfur dioxid, SO_2, which is used for the purpose of fumigation or destroying alleged dis-ease germs. This SO_2 dissolved in water gives H_2SO_3, sulfurous acid. By oxidizing this another part of oxygen is added, forming H_2SO_4. All three of these compounds are poisonous and harmful.

Hydrogen Sulfid, H_2S, is a poisonous gas with a bad odor. It is formed by the decay of certain food substances, such as eggs. Sometimes this gas occurs in intestinal fermentation.

Carbon Disulfid, CS_2, is used extensively to kill insects. The salts of sulfuric acid, or sulfates, are quite important, and many of them are poisonous. Glau-

ber's salt (sodium sulfate Na_2SO_4) and Epsom salts (magnesium sulfate $MgSO_4$) are extensively used by the medical profession as purgatives. These poisons cause the intestines to act violently in an effort to throw out the offending substances.

Vegetable Sulfur in the Human Body—I have herein mentioned a number of sulfur compounds which are foreign or harmful to animal life. In wonderful contrast to this is the fact that sulfur is an essential constituent of the human body, and in certain complex compounds with nitrogen and other elments, forms the brain, nerves, and many other body-tissues.

Phosphorus—This element is useful in the manufacture of common matches because it possesses the power to ignite by friction. The things of interest to the food scientist, however, are the salts

of phosphoric acid. These enter largely into the bones, and to some extent into the nerves and other organs of the body.

SILICON is the element which, combined with oxygen, forms the greatest part of the rocks and the sand of the solid earth. It forms the shell of certain sea-animals. In the human body it is found in the teeth and in the bones in very small quantities.

METALS—Metals, when united with oxygen and hydrogen, form the bases of nearly all the substances studied in this lesson. When these act with acids they produce the salts. It is these salts of the metals that are of most interest to us. The salts of common metals, such as copper, tin, lead, and iron do not enter into the composition of the human body, and many of these are decidedly poisonous, especially those of copper, lead, mercury, and arsenic.

Importance of metals to digestive juices

The metals whose salts are found in the body are sodium, potassium, calcium, and magnesium. These metals in their elementary state are seldom seen outside a chemist's laboratory, but we can judge of their importance when we remember that the digestive juices contain these metals. The teeth and all bony substances are formed from these compounds, and the ability of all body-fluids to carry food material in solution depends upon a definite per cent of these metal salts. The study of minerals, or of mineral salts contained in food, together with their uses in the body, forms an important subdivision of food chemistry.

Iron—Iron is mentioned separately from other metals because it not only yields salts that occur in small quantities in the body, but because, like sulphur, it enters into the complex nitrogenous portions of the body to form part of the living substance itself.

This organic iron, as it is sometimes called, occurs chiefly in the red blood-corpuscles.

Iron in patent medicines

The patent medicines which are exploited for the iron they contain, are frauds so far as nourishing the body is concerned. The popular deception is caused by the general belief that all compounds containing the same elements are alike in their uses. One might as well swallow iron filings as to endeavor to build red blood corpuscles out of the mineral solution of iron.

LESSON III

ORGANIC CHEMISTRY

LESSON III

Organic Chemistry

CARBON

In this lesson I will consider carbon and carbon compounds, which are the bases of all foods and living matter. I will devote but little attention to theories and technicalities, but will discuss the subject from scientific and practical standpoints.

Wood, flesh, and other products of vegetable or of animal life blacken when heated to a sufficiently high temperature. This blackening is due to the presence of carbon. If such substances are heated with an abundant supply of air, the carbon combines with oxygen and forms a colorless gas; that is, the carbon burns.

Sources of carbon

The principal form in which carbon occurs in nature is in combination with other elements. It occurs not only in all living things, but in their fossil remains, as in coal. All products of plant life contain carbon, hydrogen, and oxygen. Among the more common of these are sugar, starch, wood, etc. Most products of animal life contain carbon, hydrogen, oxygen, and nitrogen. Among these are albumin, fibrin, casein, etc.

Carbon occurs in the atmosphere in the form of carbon dioxid or carbonic acid gas. It is also found in the earth in the form of salts of carbonic acid or carbonates, such as limestone, marble, and chalk.

Various forms of carbon

The pure element, carbon, is found in nature in the form of diamonds, which are pure crystallized carbon. Small diamonds are now made artificially in electric furnaces. Crystallized carbon also occurs

in nature in the form of graphite, from which lead pencils are made. Charcoal, lampblack, and coke are forms of amorphous carbon which contain a very small percentage of impurities.

Properties of carbon

Notwithstanding the marked difference in their appearance, the various forms of carbon have some properties in common. They are insoluble in all known liquids. They are tasteless, odorless, and infusible at ordinary temperature. When heated without access of air, they remain unchanged unless the temperature is very high, in which case they unite with oxygen and are consumed, forming carbon dioxid.

INORGANIC CARBON COMPOUNDS

CARBON DIOXID (CO_2)

The principal compound of carbon and oxygen is carbon dioxid, often called

carbonic acid gas. This gas is always present in the air. It issues from the earth in many places, particularly in the neighborhood of volcanoes. With it many mineral waters are naturally charged.

How carbon dioxid enters the air

Carbon dioxid is constantly formed by many natural processes. Every animal that breathes gives off carbon dioxid from its lungs. This gas is also formed whenever ordinary combustible materials are burned. The natural processes of decay of both vegetable and animal matter tend to convert the carbon contained therein into carbon dioxid, which is thrown off and absorbed into the air. The process of alcoholic fermentation, and similar processes, also give rise to the formation of this gas. When fruits ripen, fall, and decay, the sugar, which all fruit-juices contain, is changed to alcohol and carbon dioxid.

RELATION OF CARBON DIOXID TO LIFE

Action of plants upon carbon dioxid

Carbon dioxid is an important factor in the life activity of the earth. The leaves of plants absorb carbon dioxid from the air, and by means of the chemical activity of the green coloring-matter or chlorophyl, the plant has the power of combining the carbon dioxid with water, and with the mineral salts which have been absorbed from the earth by the roots of the plant. Sunlight is necessary to this action, especially in the manufacture of starch.

This formation of food material in plants by the combination of simple chemical substances, such as carbon dioxid and water, is one of the fundamental life-processes. Animals do not possess this power of utilizing simple or inorganic chemical compounds, therefore they must take their food substances in the more complex forms which have been created by the power of sunlight acting upon the plant.

I have already explained how carbon dioxid may enter the air. Thus we see that the carbon dioxid which is withdrawn from the air, by the growth of plants, is constantly replaced by combustion, and in this way the "carbon cycle" is completed. This is one of the most beautiful adaptations in nature. If the plant did not remove the carbon dioxid from the air, it would soon accumulate in such quantities as to become detrimental to life, and, on the other hand, if this gas were not returned to the air by combustion, by the breathing of animals, and by the decay of plants, the vegetable world would soon be without carbon dioxid, which is as essential to plant life as is the oxygen of the air to animal life.

The wonderful carbon cycle

CARBON MONOXID (CO)

This compound is formed when a substance containing carbon is burned in an

insufficient supply of air, as for example when the draught is partly shut off in a stove.

Carbon monoxid is a colorless gas. It burns with a blue flame, forming carbon dioxid. The blue flame seen playing over the embers of a coal fire is carbon monoxid burning. This gas is extremely poisonous. Carbon dioxid, CO_2, is not poisonous. The poisonous properties of illuminating gas are due to the carbon monoxid which it contains.

Properties of carbon monoxid

ORGANIC CARBON COMPOUNDS

The carbon compounds thus far considered have been mentioned to illustrate a few of the simpler or inorganic forms of carbon. We will now begin the study of *organic chemistry* or the compounds of carbon which are commonly found only in plant and animal substances.

Carbon has wonderful powers of com-

bination with other chemical elements, and may combine with the same elements in thousands of different proportions. This property of carbon to form so many different compounds is considered one of the fundamental facts of chemistry upon which life depends. For example:

Combining power of carbon

Carbon and hydrogen compounds

Oxygen can combine with hydrogen in but two proportions—peroxid of hydrogen (H_2O_2) and water (H_2O)—while carbon and hydrogen can combine in more than a hundred different compounds. The simpler of these are acetylene (C_2H_2) and marsh gas or methane (CH_4), which is the fire-damp in mines.

The compounds containing carbon, hydrogen, and oxygen number into the

thousands. A great many substances formed in plants contain these three elements, such as fruit-acids, alcohol, sugar, and fats.

CLASSIFICATION OF ORGANIC CARBON COMPOUNDS

Only a few of the most important groups of the organic or life-formed carbon compounds will be considered in this work, namely:

a Hydrocarbons	e Organic acids
b Alcohols	f Carbohydrates
c Glycerin	g Fats
d Aldehydes and ethers	

a HYDROCARBONS

Hydrocarbons are compounds of the two elements carbon and hydrogen.

Uses of hydrocarbons in industrial chemistry

These compounds are very important in industrial chemistry. They are found in petroleum, coal-tar, etc., which were

originally formed from decaying and petrifying masses of plants. Gasoline, benzin, naphtha, acetylene, methane, etc., are some of the industrial forms by which hydrocarbons are known in commerce.

Coal-tar products

The industries based upon the chemistry of these hydrocarbons are very complex and interesting. Coal-tar yields, by repeated distillation and chemical reaction, thousands of compounds, many of which find important industrial usages. Coal-tar dyes are very numerous and of wonderful coloring power. They have been extensively used in the artificial coloring of manufactured foods. The Federal Pure Food Law attempted to prohibit this. In fact, it was the pernicious effect and extensive use of these poisons that stimulated the passage of the "Food and Drugs Act." Another interesting product of the coal-tar industry is saccharin. Saccharin has no

food value whatever, but it is 280 times sweeter than cane-sugar, and is therefore used as a substitute in sweetening some prepared foods.

b ALCOHOLS

Varieties of alcohol

To the ordinary mind the term alcohol refers only to the intoxicating element in liquors. To the chemist, alcohol has a much broader significance. There are many varieties of alcohols, of which ethyl alcohol ($C_2H_5.HO$), which is found in liquors, is only one example. Another form of alcohol which is fairly well known is wood or methyl alcohol ($CH_3.OH$).

Formation of higher alcohols

There are also higher alcohols, that is, those having more complex chemical formulas, such as butyl alcohol. In the fermentation of grains or fruits for intoxicating liquors, a small quantity of

the various higher alcohols is formed. These higher alcohols are more intoxicating and more harmful to the human system than ethyl alcohol, and must be separated from the latter by careful distillation. The poisonous property of green whisky and cheap liquors is generally due to the presence of higher alcohols.

Alcohol does not exist in normal, fresh plant or animal substances except in very minute quantities. It is formed from sugar by fermentation. This fermentation is due to a microscopic yeast-plant.

c GLYCERIN

Another form of alcohol is glycerin ($C_3H_8O_3$). It is of special interest to the food chemist because it enters into the formation of all fats.

d ALDEHYDES AND ETHERS

These are compounds containing carbon, hydrogen, and oxygen, and are closely related to alcohols. In fact, they are formed from alcohols by a process of oxidation, hence contain a little larger proportion of oxygen than the related alcohol.

How formed

An example of aldehyde with which many are familiar is formaldehyde, which is used in laboratories for the preservation of animal-tissues for dissection. This formaldehyde is a very strong germicide; that is, it is poisonous to bacteria or germs. For this reason it is used as a preservative of milk, a use which is forbidden by the "Food and Drugs Act," because formaldehyde is also poisonous to the human system.

Uses of formaldehyde

Ethyl ether, which is used as an anesthetic or to produce insensibility

to pain, will serve as an illustration of this group of compounds. When analyzing foods in chemical laboratories, ether is commonly used for dissolving fats.

Uses of ether

e ORGANIC ACIDS

It will be remembered that acids were studied in the second lesson. It was found that the common properties of acids are a sour taste, ability to combine with alkalis in the formation of salts, and that all acids contain hydrogen. These same properties that were studied in the second lesson in reference to mineral acids, such as hydrochloric and sulfuric, apply also to the organic acids. The organic acids, however, as a class are not so strong or active as the mineral acids.

Properties of organic acids

All organic acids are compounds of carbon, hydrogen, and oxygen, the same

as alcohols and ethers, the chief difference between these compounds and acids being that the acids contain a greater proportion of oxygen. One of the simplest organic acids is *formic acid* (HCO.OH). This acid is the active principle in the sting of the red ant, and also of stinging nettles. It produces blisters when applied to the skin.

Impure *acetic acid* ($C_2H_4O_2$) is very well known to all under the name of vinegar. Acetic acid may be obtained by distilling wood. If it could be manufactured cheaply enough, vinegar made from wood would be fully as wholesome as the best cider vinegars, but this being an expensive process of manufacture, the temptation of the food adulterator is to make the vinegar of sulfuric acid, which is much cheaper than the mild acetic acid, but much more harmful when taken into the body.

Process of making acetic acid

The formic and the acetic acids are

examples of a series of organic acids known as *fatty acids.* Other members of the series are—

Propionic acid	......	$C_3H_6O_2$
Butyric "	......	$C_4H_8O_2$
Palmitic "	......	$C_{16}H_{32}O_2$
Stearic "	......	$C_{18}H_{36}O_2$

Process of making soap

These fatty acids are very important to the food scientist as they combine with glycerin to form fats. When combined with alkalis under a certain temperature they form soap. Perhaps some of our older students may remember the soap kettle on the farm at home, in which lard cracklings and other fatty fragments of the animal were boiled with lye or caustic potash to form home-made soap. The chemical action that took place was a combination of these fatty acids with the caustic potash or lye. The glycerin was set free and remained in the bottom of

the kettle as soft soap. Reference will be made to these acids again, in Lesson IV, where the study of fats will be taken up in detail. (See "Fats and Oils," under Lesson IV, Chemistry of Foods, p. 122).

Oxalic Acid

There are some other forms of organic acids which do not belong in the fatty series; that is, they do not contain the same general proportions of carbon and hydrogen. One of these is oxalic acid ($C_2H_2O_4$) which is found in certain plants, such as sorrel, and is an active poison. Oxalic acid is used in the household for taking iron-rust out of cloth.

Lactic, malic and tartaric acids

Lactic acid ($C_3H_6O_3$) is the acid of sour milk. Malic acid ($C_4H_6O_5$) is found in many fruits, such as apples, apricots, currants, pears, plums, prunes, etc. Tartaric acid ($C_4H_6O_6$) is found principally in grapes. It is one of the constituent elements in the sediment found

in wine casks, and is the active principle in cream of tartar. The latter is a potassium salt of tartaric acid.

Citric acid

Citric acid ($C_6H_8O_7$) is one of the most important of the organic acids from the standpoint of the food chemist. It is the active principle of citrus-fruits, such as grape-fruit, lemons, limes, oranges, etc. Lemons contain as high as five per cent of this acid. Citric acid is often used to make lemonade, and if pure citric acid is used, the manufactured product is equal to the original, except from a sentimental standpoint of having the genuine. The danger is, as in the case of adulterated vinegar, that the manufacturer may be tempted to use cheaper mineral acids instead of citric acid.

The other above-named groups of organic compounds which are formed from the three elements carbon, hydrogen, and oxygen—(f) *carbohydrates* and (g) *fats*—are very important to the food

chemist. These will be considered in detail in Lesson IV. See pages 107-125.

ORGANIC NITROGENOUS COMPOUNDS

If to the three elements carbon, hydrogen, and oxygen, the element *nitrogen* is added, it still further increases the number of possible compounds that may be formed upon the base of the wonderful *carbon atom*. With this additional nitrogen factor, a new and a distinct quality is obtained.

The elements that make life possible

The chief characteristic of the element nitrogen is the ease with which its compounds change their chemical form. To quote the chemist, "the compounds of nitrogen are very unstable." Nearly all explosives are nitrogenous compounds. When this element, nitrogen, is combined with the wonderful variety of compounds formed by carbon, we have not only a great many intimately related yet dis-

tinct substances, but compounds which readily change from one form to another. These are the distinctive qualities or conditions necessary, from a chemical standpoint, to make the processes of life possible. *Protoplasm, which is the basis of all life, is formed by an intimate mixture of a number of complex chemical compounds, the chief elements of which are carbon, hydrogen, oxygen, and nitrogen.*

Importance of nitrogenous compounds

The organic compounds containing nitrogen are very numerous and very interesting. As all tissues and substances of the animal body contain nitrogen as a necessary element, we can see why this group of compounds is of great importance to the student of food science.

Some of the nitrogenous compounds which are *not* available as nutritive substances, and many of which are poisonous or harmful to animal life, will be considered in Lesson IX, under "Alkaloids and Narcotics." (See Vol. II, p. 349.)

The principal nutritive substances, and proteids or compounds containing *available food nitrogen*, will be considered in Lesson IV.

LESSON IV

CHEMISTRY OF FOODS

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Four general classes of food

The chemistry of carbon compounds and the general composition of plant and of animal substances were discussed in Lesson III. We are now prepared to take up the chemistry of food. The chemistry of food substances will be considered under the common divisions of carbohydrates, fats, proteids, and mineral salts. (See "Classification of Organic Carbon Compounds," Lesson III, p. 89.)

Classes vs. groups of related compounds

In the food tables and analyses commonly published, the above terms are used with very little explanation, and read by the average person with meager comprehension. When one reads that a food is composed of glucose, citric acid, or globulin, he

is likely to become confused, not being able to understand how a food at one time can be said to be composed of carbohydrates, proteids, and fats, and at another time to be composed of other substances. The explanation is that the first classification does not refer to definite chemical substances, but to groups of related compounds having properties in common.

The different methods of analyzing food

There is still another way of giving the chemical composition of a food, namely, to specify the chemical elements that it contains. It will be remembered that the relation between chemical elements and chemical compounds was explained in the first lesson. As an example, I will take the analysis of milk. We will first say that milk contains a certain percentage of protein, carbohydrates, and fat. We might then say that the proteid of milk is part casein and part albumin, and that the albumin contains certain percentages of oxygen, sulfur, etc.; also

that the chief carbohydrate in milk is milk-sugar, which in turn is composed of carbon, hydrogen, and oxygen. Or, we could consider the milk as a whole, without dividing it into groups, and give the per cent of each chemical element in the milk. Thus, the carbon of the proteid, milk-sugar, and fat would be all considered together, and show a certain per cent of carbon in the milk as a whole.

CARBOHYDRATES

The word *carbohydrate* means *carbon combined with water;* that is, the element carbon is combined with hydrogen and oxygen, which exist in the carbohydrate compound in the same proportion as they exist in water.

The carbohydrates are closely related chemically to the aldehydes and the alcohols, so far as their composition is concerned (See "Aldehydes and Ethers," Lesson III, p. 93), but this does not

imply that they have the same physiological effect in the animal body.

CLASSIFICATION OF CARBOHYDRATES

The carbohydrates are divided by the chemist into three classes known as

a MONOSACCHARIDS
b DISACCHARIDS
c POLYSACCHARIDS

The principal subdivisions found in these classes of carbohydrate foods are given in the following table, arranged in the order of their importance:

Monosaccharids	*Disaccharids*	*Polysaccharids*
1 Glucose or grape-sugar (formerly called dextrose)	1 Cane-sugar	1 Starch
2 Pentoses (of which there are several)	2 Maltose	2 Glycogen
	3 Lactose	3 Cellulose
3 Levulose		4 Gums
4 Galactose		5 Inulin

a MONOSACCHARIDS

1 GLUCOSE OR GRAPE-SUGAR ($C_6H_{12}O_6$)

Glucose or grape-sugar is the most important sugar known from the standpoint of the physiological chemist. This sugar is normally found in considerable quantities in human blood, and is absolutely essential to the life-process, a fact which forms an amusing contrast with the popular conception of the term glucose as something injurious or poisonous.

Sources of glucose

Glucose is found in honey, and in nearly all fruits, grains, and sweets. (For "Sweets" see Lesson VIII, Vol. II, p. 324). It may be taken into the human body directly from such fruits, or it may originate by the digestion of other carbohydrates.

Pure glucose crystallizes and resembles cane-sugar, but is not so sweet. The

glucose of commerce, sold as sirup, is a product manufactured from corn, or other starches, and will be considered more in detail under the heading *starch*. (See "Polysaccharids," p. 114).

2 PENTOSES ($C_5H_{10}O_5$)

Sources of pentoses

Pentoses form a group of sugars, the chemical formula of which contains five atoms of carbon. Each different pentose could be studied in detail by the chemist, but the pentoses are of no particular interest to the food scientist. They exist, however, in the coarse parts of plants, such as stalks and leaves, and are of considerable importance in animal feeding. From the standpoint of human food we will remember that the carbohydrates of green plants contain a percentage of these pentoses, but as they are never removed from the plant separately, as are other sugars, we must

consider their physiological effect in the particular plant rather than separately.

3 LEVULOSE ($C_6H_{12}O_6$)

This is the companion sugar to glucose and exists in many fruits. Levulose is often called "fruit-sugar." The composition of levulose is exactly the same as glucose, but the atoms are combined in different ways.

Levulose, for all practical purposes, may be considered the equivalent of glucose in the human body. It is sweeter than glucose and more closely resembles cane-sugar.

4 GALACTOSE ($C_6H_{12}O_6$)

Galactose, which is of the same composition as levulose, is another companion sugar to glucose, and is formed by the digestion of lactose or milk-sugar.

b DISACCHARIDS

1 CANE-SUGAR ($C_{12}H_{22}O_{11}$)

Just as there are three monosaccharid sugars with six carbon atoms each, so there are three disaccharid sugars which have twelve carbon atoms each. The first of these is cane-sugar. It is commercially made from either sugar-cane or sugar-beets, and is identical in chemical composition from either source.

Cane sugar, when digested in the human body, or by artificial means, combines with water, and forms glucose and levulose, as shown by the following equation:

$$\begin{array}{ccccccc} C_{12}H_{22}O_{11} & + & H_2O & = & C_6H_{12}O_6 & + & C_6H_{12}O_6 \\ \text{Cane-sugar} & + & \text{Water} & = & \text{Glucose} & + & \text{Levulose} \end{array}$$

2 MALTOSE ($C_{12}H_{22}O_{11}$)

Maltose is the second member of the disaccharid group, and is of the same

composition as the other two. Maltose derives its name from malt. It is formed from the starch of grains by a process of digestion which may be performed in the animal body, or by the process of malting. Maltose, like cane-sugar, can be further digested into monosaccharid sugars, but upon such digestion, instead of forming two separate simple sugars, it is wholly converted into glucose.

Maltose—how formed

The reader will now understand the meaning of the terms *monosaccharid*, *disaccharid*, and *polysaccharid*. *MONO*, which means *one*, is the simplest form of carbohydrates. Disaccharids (*DI*, meaning *two*), split up to form two simple sugars. Polysaccharids (*POLY*, meaning *many*) are complex compounds which form many simple sugars.

3 LACTOSE ($C_{12}H_{22}O_{11}$)

Lactose exists in milk and has the same formula as cane-sugar. Milk

contains about five per cent of this sugar.

When lactose is digested it combines with water as does cane-sugar, but instead of yielding glucose and levulose, it yields glucose and galactose.

c POLYSACCHARIDS

1 STARCH

The chemical formula of starch and other polysaccharids is written $(C_6H_{10}O_5)n$. This means that the proportion of the elements is according to the figures given, but the number of atoms that are supposed to be combined is many times greater than five, and is not accurately known. This is purely theoretical, and of no practical importance, except that it shows that the polysaccharid is capable of being digested or broken up into many simple carbohydrate compounds.

Starch is the most abundant carbo-

hydrate known. It is the chief constituent of all cereals, and is found in large quantities in green fruits and tuberous plants. Starch occurs in small granules, varying greatly in size in different foods.

Sources of starch

Potatoes are composed chiefly of starch and water. The starch grains of potatoes can almost be distinguished with the naked eye. These starch granules are not atoms or molecules in the chemical sense, but are small receptacles in which starch has been deposited by the growing plant. When cooked or boiled in water these starch grains swell into a mushy, pasty or gelatinous mass; when cooked in dry heat until they begin to turn brown, they are changed into a compound related to the gum group, known as dextrin.

Potato starch

Starch does not dissolve in water as do sugars. If starch is treated with digestive fluids, such as saliva, or with certain acids, it goes through a complex

process of digestion in which it is first turned into soluble starch, then into the various forms of dextrin or gums, and finally into maltose or malt-sugar.

Solubility of starch

Corn-starch, treated with weak sulfuric acid, changes the starch into glucose. The ordinary glucose or corn-sirup is not all changed by this process, into pure glucose, but contains some maltose and other gummy compounds; hence it will not crystallize or granulate into pure sugar. After the acid has changed the starch into glucose it (the acid) is neutralized with an alkali. A crude compound is thus formed, which settles to the bottom of the tank, and from which the glucose can be easily separated. Commercial glucose is now very extensively used in the manufacture of various food products, especially confectionery. Pure glucose is a wholesome food, but there is some danger that the commercial product

How corn-starch is changed into glucose

may (due to carelessness in manufacturing, or to the use of cheap and impure acid) contain various mineral poisons. Government testing of glucose and similar manufactured products is, in the writer's opinion, fully as essential as the government inspection of packing-house products.

How starch is changed into maltose

Just as glucose may be manufactured from starch treated with dilute acids, so maltose may be made by treating starch with malt. The brewing of beer depends upon the chemical changes induced in starch by malt. Barley is ordinarily used for this purpose. The barley is sprouted in a warm, damp room, and a process of starch digestion begins, which is necessary in order that the young barley sprouts may grow. This changes the starch into maltose. The digestive principle developed in the barley-malt may be utilized to malt other grains by mixing them with the sprouted barley.

If this process of malting is stopped at the proper time, and the sugar dissolved, and extracted, a product is formed consisting chiefly of the sugar maltose. This is the basis of malt extract, malt honey, and many similar foods put on the market, which are claimed by the manufacturers to have wonderful dietetic and curative values.

Maltose in foods

2 GLYCOGEN

Glycogen—how formed and where stored

Glycogen is commonly called animal-starch. It exists in the liver in small quantities. All carbohydrates are digested in the alimentary canal and absorbed into the blood in the form of simple sugars of the glucose group. When these sugars reach the liver they are again built up into a complex carbohydrate very similar to starch in composition. This glycogen or animal-starch is stored

in the liver until the body has need of it, when it is changed into glucose and given back to the body in the form of energy. (See "Metabolism of Carbohydrates," Lesson VI, p. 202).

3 CELLULOSE

Cellulose—its purpose, source, and importance

Cellulose, from the standpoint of human nutrition, is not a food product, being insoluble by the digestive juices, but it is very important in the digestion and the alimentation of other foods. Its chief purpose is to excite stomach and intestinal peristalsis. All plant products in their natural form contain some cellulose, though the percentage is very small in such grains as rice and barley. The bran of wheat or of corn is chiefly cellulose. Wood is almost pure cellulose.

Cellulose can be digested by strong acids into simple carbohydrates, in the same way that starch may be. Sugar

can be manufactured from wood or rags, but the process is yet too expensive to be applied commercially. Some of us may live to see the time when the chief food of mankind will be manufactured from scrap lumber and waste paper. Bacteria have the power of digesting cellulose. The bacterial action or fermentation in the human intestines may cause a small amount of cellulose to be digested, but the quantity is of no consequence from a nutritive point of view.

4 GUMS

The gums include a group of rather complex carbohydrates which are intermediate between starches and sugars. From plants are derived many varieties of gums which have various commercial uses in the market, such as gum arabic.

I have already spoken of the formation of dextrin from starch. Dextrin has no particular dietetic qualities that do not

exist in starch. It is, in fact, starch arrested at an intermediate point of digestion.

Pectins in fruits

Pectins are a group of gummy substances found in fruits, especially green fruits which are in the process of being formed into sugar. These pectins form the basis of fruit jellies. Green grapes, as every housewife knows, will make better jelly than ripe grapes. This is because the pectins in ripe grapes have been transformed into sugar. The pectins in fruit are in most cases wholesome enough, though it would seem the better part of wisdom to eat all fruits in the ripened state, after Nature has completed her work.

5 INULIN

Inulin is a compound closely related to starch, and upon digestion with acids, yields levulose just as starch yields glu-

cose. It is of no particular interest to the food chemist, as it exists in but very small quantities in starch, and has no distinct dietetic value.

FATS AND OILS

Composition and formation of fats and oils

The fats and oils in food products, whether of plant or animal origin, contain the elements carbon, hydrogen, and oxygen. These fats are formed by uniting the fatty acids with glycerin, which belongs to the alcohol group. The particular fat that is formed takes its name from the acid which enters into its composition; thus stearic acid unites with glycerin to form the fat stearin.

The following table gives the names of a few of the more common fatty acids and their corresponding fats:

Stearic acid	Stearin
Palmitic acid	Palmitin
Oleic acid	Olein
Butyric acid	Butyrin

A fat from any source will usually contain several of these chemical compounds.

Distinction between tallow and lard

The ordinary animal fats, such as tallow and lard, are formed chiefly of the two fats stearin and olein. The different proportions of these fats will determine the melting point or hardness of the mixed product. Olein is a liquid at ordinary temperature, while stearin is solid. The reason that tallow is a firmer fat than lard or butter is because it contains a larger per cent of stearin.

Olive-oil, cottonseed-oil, and other vegetable oils contain large per cents of olein, which accounts for their being liquid at ordinary temperature.

Dairy butter vs. artificial butter

Butyrin is a fat found in small quantities in dairy butter, and does not exist in cottonseed-oil and other fats from which oleomargarin is manufactured. This is the reason that artificial butter lacks the flavor of the dairy product, and this

is remedied to some extent by churning the fats of the cottonseed-oil and tallow with fresh cream, which imparts a small quantity of the butyrin and similar compounds to the oleomargarin and gives the characteristic flavor of butter.

Oils as active poisons

Besides the more common fats herein mentioned there are many other fats that exist in certain vegetable oils in small proportions. These fats give the oils their characteristic properties, and may render them unfit for food. Some oils are active poisons, such as croton-oil, which is the most powerful physic known. The power of all physics and cathartic drugs is measured by the active poisons they contain.

Packing-house uses of stearin and olein

When fats are heated to a high temperature they decompose and form various products, some of which are irritating and poisonous to the human system. In the manufacture of packing-house and

cottonseed products the stearin is often separated from the olein. The granular appearance of pure leaf lard is due to crystals of stearin. In the packing-house stearin is separated from the tallow in large quantities. The stearin is used to make candles, etc., while the olein is used for food purposes in this country in the form of oleomargarin, while in Europe it is used under its right name as a cooking product. It is equally as wholesome, if not more so, than lard.

Rancid fats made edible

Fats may become rancid; this is caused by the decomposition of fat due to its uniting with the oxygen of the air. Rancid fats and nut-kernels can be restored and made edible by heating them in an oven until the oxidized fat is neutralized by the heat.

PROTEIDS OR NITROGENOUS FOOD SUBSTANCES

The food substances which contain nitrogen are commonly called proteids,

or, if these compounds are considered together, the name protein may be given the group. Protein is not a single compound, but includes all substances which contain the element nitrogen in such combinations as are available for assimilation in the human body.

Proteids defined

Protein is the most important group of nutrients in the animal body. The proteid substances in the body must be formed from proteids taken in the form of food, because only proteid foods contain the element nitrogen. All proteids contain nitrogen, but all nitrogen does not contain protein. All proteids, therefore, are nitrogenous compounds.

Only proteid foods contain nitrogen

The animal body does not possess the power of combining elementary nitrogen with other elements. Bacteria have the power to utilize the nitrogen of the air to form mineral salts or nitrates. Plants

Formation of organic nitrogen

have the power to unite the nitrogen derived from these nitrates with carbon, oxygen, and hydrogen. In this way organic nitrogen, or proteids, are formed. The animal body may digest these proteids, however, and transform them into other proteid compounds. All proteids contain carbon, hydrogen, oxygen and nitrogen; most of them contain sulfur, and a few contain phosphorus, iron, copper, and bromid.

The percentage by weight of the various elements which form proteid matter is about as follows:

Carbon	52%
Hydrogen	7%
Oxygen	22%
Nitrogen	16%
Sulfur	2%
Phosphorus	1%

The following table gives three groups of proteid substances:

Simple Proteids	*Compound Proteids*	*Albuminoids*
Albumins	Respiratory pigments	Collagen
Globulins	Gluco Proteids	Gelatin
Nucleo albumins	Nucleins	Elastin
Albuminates	Nucleo proteids	Reticulin
Coagulated proteids	Lecith albumins	Keratin
Proteoses (Albumoses)		
Peptones		

Amido compounds

Besides these real proteids there are a few substances known as amido compounds which exist in small quantities in vegetables, and a number of nitrogenous substances which exist in meat and meat extracts, which are not true proteids, as they have little or no nutritive value, but act as stimulants or irritants in the body.

Ptomains—how formed

Ptomains are another class of substances which are often found in food products. They are formed by the growth of bacteria, and are in reality the nitrogenous waste-products of bacterial life. Ptomains develop in meats and dairy

products held in cold storage, and are sometimes the cause of serious poisoning. Nitrogenous waste-products will be further discussed in Lesson VI, under "Metabolism of Proteids." (See p. 209.)

Sources, coagulation and solubility of albumin

Albumin is one of the commonest and simplest forms of proteids known. It is found in the white of eggs, in milk, and in blood. It is coagulated by heat, and by certain chemicals, such as acids, alcohol, and strong alkalis. Albumin is soluble in water and in weak solutions of salt, but it is not soluble in very strong salt solutions.

Sources and properties of globulins

Globulins are much like albumin, but are not soluble in water. They are, however, soluble in dilute salt solutions. Globulins exist in considerable quantities in the yolk of eggs, and in the blood. The globulin in the body could not remain in solution if there were not always present

a small quantity of salt in the blood. There are several types of globulins. The fibrinogen of the blood, which coagulates, forming clots, when the blood is exposed to the air, is a globulin. Hemoglobin, which is the chief component of red blood-corpuscles, and which unites with the oxygen in the lungs and carries it to the various tissues of the body, is another form of globulin, and one which contains a considerable amount of iron.

Sources of casein

Casein is the most important proteid substance in milk, and is familiar to all as the curd or white substance of clabbered milk. A related form of vegetable casein is found in leguminous seeds, such as beans and peas.

Sources of proteoses and peptones

Proteoses and peptones are proteids that are formed by the digestion of other proteids. They exist in the alimentary canal in the partly digested food. Peptones are readily soluble, and for this reason are

easily absorbed through the walls of the digestive organs. (See Lesson V, "Digestive Organs"—[The Stomach], p.137; also "Composition of Gastric Juice," p. 147).

MINERAL SALTS IN FOOD

Vegetable mineral salts vs. common table salt

The subject of salt in food has received considerable attention and discussion by scientific investigators, and many theories have been advanced by those interested in hygiene as to the effect of common salt used in food. The tissues and organs of the body contain certain salts, without which life could not exist, but it does not follow that these salts need to be supplied in mineral form. Common table salt is an inorganic substance, while the mineral salts in green and fresh vegetables are organic, and readily convertible, therefore a valuable aid in the digestion of other foods. A diet of sugar, pure oil, and artificially prepared proteids would

be absolutely unwholesome and would fail to nourish the body for any length of time because of the lack of mineral salts.

Foods containing mineral salts

All natural food products, whether of vegetable or animal origin, contain a limited but ever-present amount of mineral salts. This is especially true of milk, eggs, and the seeds and green portion of plants. The amount of salts in the human body is considerable, especially the calcium phosphates of the bones, but the salts that need to be supplied daily in food is small because the salts are not consumed as rapidly as are other elements of nutrition.

Some grains, especially rice and corn, are somewhat deficient in salts. At the

Grains deficient in salt

Kansas Experiment Station some pigs were fed exclusively on corn, and others on grain and green forage. At a certain age the pigs were killed, and the bones weighed and tested for strength. The

bones of the pigs which had been fed on a corn diet, which is deficient in mineral salts, were about half as heavy and strong as the bones of the pigs fed in a more natural way.

Lesson V

CHEMISTRY OF DIGESTION

DIGESTIVE ORGANS AND DIGESTIVE JUICES

FIRST—THE MOUTH:

The three salivary glands of the mouth secrete the saliva, which is an *alkaline* substance containing a digestive enzym called ptyalin.

The saliva begins the digestion of starch and moistens food to facilitate swallowing.

SECOND—THE STOMACH:

The gastric juice secreted by the mucous lining of the stomach is an *acid.* It contains hydrochloric acid and pepsin, which act on proteids, changing them to *proteoses* ("intermediate products formed naturally in the process of digestion") and peptone.

The gastric juice also contains *rennet,* which acts directly on milk, and indirectly on all proteids.

THIRD—THE LIVER:

The liver secretes a digestive fluid called bile, which is an *alkaline* substance. Its

chief purpose is to emulsify fats and to supply the alimentary tract with the requisite amount of moisture.

Fourth—THE PANCREAS:

The pancreatic juice, secreted by the pancreas, is an *alkaline* and slightly *acidulous* substance. It contains three enzyms, the names and action of which are as follows:

Amylopsin completes the digestion of starch

Trypsin completes the digestion of proteids

Steapsin converts fats into fatty acids and glycerin

Fifth—THE SMALL INTESTINES

The intestinal juices secreted by the small intestines are *alkaline* substances which change sugar and maltose into glucose, and perform the last step in the process of breaking up or subdividing food so fine that it will pass through the intestinal walls into the circulation.

LESSON V

Chemistry of Digestion

Alternation of digestive juices

The digestive juices of the human body are five in number, namely: Saliva, gastric juice, bile, pancreatic juice, and the several intestinal juices. Beginning with the saliva these juices alternate, first an alkali, then an acid. It is the opinion of the writer that this alternating plan is carried on throughout the entire intestinal tract, as the final dissolution of food matter takes place in the intestinal canal. These five juices are secreted from the blood by special cells or glands. Each of these juices contain one or more enzyms or digestive principles. These enzyms are highly organized chemical compounds which have the property of changing other chemical compounds

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without being destroyed or used up themselves except in minute quantities.

Malt, which was studied in the last lesson, and which is produced by the sprouting of barley, is a true digestive enzym of the barley. Yeast-cells are minute plants which secrete an enzym that causes the fermentation of bread. It was formerly thought that the fermentation of yeast could not take place except in the presence of a living cell. This has now been disproved, as a German scientist has succeeded in grinding up yeast-cells and filtering off the chemical compound or true enzym which causes the fermentation of sugar.

Malt and yeast-cells

It is now recognized by scientists that all processes of fermentation and digestion found in plant and animal life are due to definite chemical compounds known as enzyms. The action of digestion is truly a chemical one, and could take

Fermentation due to enzyms

place without the body as well as within, if we could manufacture the proper enzym and could produce the exact conditions of temperature, moisture, etc., that are found in the human digestive economy.

Predigested foods

The manufacture of predigested foods depends upon various processes of fermentation, or upon the digestion that may be carried on by inorganic chemical agents, such as acids, or by the ferments of bacteria, or other forms of life. The following are illustrations of these processes of predigestion:

1 The manufacture of glucose from starch by the action of sulfuric acid

2 The malting of starch for the production of malt-sugar or of fermented liquors

3 The making of cheese by the action of the enzym rennet which has been extracted from the stomach of a calf

A great amount of discussion, pro and con, has been raised over the subject of predigested food. The foregoing examples will show that the subject of predigested food, taken in its broadest sense, cannot be dismissed summarily with either approbation or disapproval. We must consider the particular chemical process involved in each case and the final chemical products, as well as its mechanical condition. These things must be taken into consideration when we pass an opinion upon the wholesomeness of a so-called predigested food.

With this diversion to illustrate the breadth and the importance of the action of enzyms, I will now return to the consideration of the chemical action of the human digestive organs.

SALIVA

The saliva is the digestive juice of the mouth. It is secreted by three pairs of

salivary glands. The secretions from these three glands are slightly different in composition, but for our purpose may be considered as one secretion. The saliva is an alkaline fluid, and the principal enzym that it contains is a starch-digesting enzym known as ptyalin, which can act only in an alkaline solution. As the gastric juice is strongly acid, the digestive action of the saliva is stopped soon after the food has entered the stomach, and the enzym is of no further use. The action of the saliva is very weak, and the amount of starch digestion which is accomplished in the mouth is comparatively insignificant.

Starch digestion in the mouth

The chief function of the saliva is to moisten food and to facilitate swallowing.

Saliva and mastication

From these statements one might first infer that the emphasis given to thorough mastication is unwarranted. In fact, the mastication of food has a much more

important function than the digestion of starch by saliva. This subject will be referred to again when the physical condition of food as a factor in digestion, and the nervous control or co-ordination of the various functions of the digestive system are considered. (See "Composition of Gastric Juice," p. 147.)

GASTRIC JUICE

Chief function of the stomach

The importance of the stomach as an organ of digestion has been overestimated in modern times. From the discussions in the average text-book and physiology, one would be led to believe that the stomach is the only organ of digestion, when, as a matter of fact, the chief purpose of the stomach is that of a receptacle for the storage of food for digestion further on. I do not mean by this statement that there is no digestive action in the stomach, but I do mean to say that there

are no digestive processes completed in the stomach, and that all foods which are acted on by the gastric juice can also be acted on by the digestive juices in the intestines. This has been proved by the fact that surgeons have successfully removed the entire stomach from both animals and men without seriously interfering with the nutrition of the body. They merely had to eat more often, as the depot or storage receptacle had been removed.

Inaccuracy of digestive tables

The stomach should be considered as a preliminary organ of digestion. The tables published in the physiologies giving the digestibility of various foods as so many hours, refer entirely to the length of time it takes for the food to pass out of the stomach. According to these tables boiled rice is given as one of the most digestible of foods. As a matter of fact, the chief reason why rice passes out of the stomach more quickly than

other grains, is because it contains practically nothing but starch, and as starch is not digested in the stomach, the rice is passed on to the next station where it can be acted on by an alkali.

Comparison of predigested and uncooked cereals

In this connection it becomes necessary to refer to the interpretation of the experimental results obtained by investigators at the Battle Creek Sanitarium. In these experiments cereal products which had been put through various processes of predigestion were compared with uncooked whole wheat, the contents being removed from the stomach after a given period. The results of this experiment showed a greater amount of starch digestion in the case of the dextrinized or super-cooked foods. These results were published as proof that starchy foods should be put through a process of super-cooking, dextrinization or predigestion. To those who are not familiar with food chemistry, such results would appear

very convincing, but to a well-informed food scientist they only illustrate how misinterpretation of scientific facts may indicate conclusions opposed to the truth.

Starchy foods are not intended by Nature to be digested in the stomach, but in the intestines, and the processes of partial digestion of these foods, by artificial means, before entering the stomach, serve only to interfere with Nature's plan, and to deprive both the stomach and the intestines of their natural functions.

COMPOSITION OF THE GASTRIC JUICE

Action of pepsin on proteids

The gastric juice contains three principal enzyms or digestive principles. These are hydrochloric acid, pepsin, and rennet. The hydrochloric acid and the pepsin are secreted by different cells, and could be considered as separate digestive juices, but as the action of one is de-

pendent upon the other, I will consider these actions as one. Pepsin, in the presence of hydrochloric acid, acts on proteids, and changes them into proteoses and peptone. Comparatively little food is completely peptonized in gastric digestion. Proteoses are intermediate products between food proteids and peptone, being the principal product of the action of the gastric juice. Thus it is seen that this stomach-action is only preparatory for the digestive processes of the intestines.

Peptone and proteoses

The gastric juice does not act on fat, but in the case of animal food, in which the membranes or connective tissues that enclose the fat-cells are formed of proteid material, the gastric juice sets the fat-globules free by dissolving these enclosing membranes.

Action of gastric juice on fat

The chief action of hydrochloric acid in the stomach is to aid the action of the

pepsin. Pepsin alone has no digestive power. There are no other acids produced by the secretive glands of the stomach. If other acids are found in the contents of the stomach, it is because they have been taken in with the food, or produced by abnormal fermentation.

Purpose of hydrochloric acid

The source of hydrochloric acid is from the sodium chlorid or common salt of the blood. The secreting cells of the stomach-glands are thought to have the power to form hydrochloric acid by uniting the chlorin of the salt with the hydrogen of the water. This is a very unusual chemical process, and has not yet been successfully produced in a laboratory.

How hydrochloric acid is formed

One of the chief functions of hydrochloric acid in the stomach is that of an antiseptic. In other words, hydrochloric acid kills bacteria. This is not true of all bacteria, for some germs can live in an

Hydrochloric acid as an antiseptic

acid medium, while others may live best in an alkaline solution. The alternation of the digestive juices from alkali to acid is a provision of Nature which has a dual purpose:

1 To reduce food to the finest possible solution; that is, to subdivide or to digest food elements into a form that will admit of assimilation and use

2 To destroy bacteria and enzyms of plant and animal origin that are taken into the digestive tract with food

(These two facts constitute additional reasons for the thorough mastication of food)

Object of alternating digestive juices

By such plan Nature provides for the digestion of food only by such enzyms and ferments as will produce a finished product wholly suited to the particular requirements of the body. When we at-

tempt by artificial processes to digest our food with other enzyms than those of our own digestive organs, or take into the stomach large quantities of food without proper mastication, which causes fermentation, we may expect that the nutritive material supplied to our tissues will not be perfectly adapted to the needs of human cell-growth, and, as a natural result, consequent derangement of the body-functions will take place.

Rennet

The rennet of the gastric juice is primarily for the purpose of digestion. Other than this it has no particular function that has yet been discovered.

Why stomach does not digest itself

The problem as to why the stomach does not digest itself has puzzled scientists for many years. Investigations of the twentieth century have at last solved this fascinating question. The walls of the human stomach are composed of proteid material, and should be dissolved

by the gastric juice according to all known chemical laws. The explanation formerly given was that the stomach did not digest itself because it was alive. This answer did not satisfy scientists.

Antipepsin in the blood

There has recently been discovered an enzym, known as antipepsin, which is secreted by the cells in the stomach-walls. This antipepsin destroys the action of the pepsin, thus in turn preventing its action on the stomach-wall itself. Were antipepsin secreted in sufficiently large quantities to mix with the food in the stomach-cavity, no digestion could take place. The presence of this antipepsin in the stomach-walls has been proved in the following manner: The arteries leading to a portion of the stomach-wall of a dog was severed. This portion, receiving no blood supply, did not form the usual amount of antipepsin. The secretion of pepsin went on in the remainder of the animal's stomach, but digested that por-

tion of the stomach-wall which was receiving no blood supply; that is, secreting no antipepsin.

BILE

Function of bile

The bile is a juice secreted by the liver and is alkaline in character. It is collected by the biliary ducts to be conveyed into the duodenum. The most important constituents of bile are bile salts and sodium glycocholate. The chief purposes of bile are to emulsify fats, thus aiding them to pass through the intestinal walls, and to stimulate intestinal peristalsis.

PANCREATIC JUICE

Function of the pancreas

The pancreas is a secretive gland located entirely outside of the intestinal walls, and produces a juice which is poured into the small intestines at the point where the bile enters. Pancreatic juice

is acidulous, and also strongly alkaline. As soon as the food, passing from the stomach, comes in contact with the pancreatic juice and the bile, the acid is neutralized, and the mass becomes alkaline.

The pancreatic juice contains three important enzyms:

1 Amylopsin—acts on starch

2 Trypsin—acts on proteids

3 Steapsin—a fat-splitting enzym

Pancreatic juice also has the power of coagulating milk, and is believed to contain some rennet.

Power of amylopsin

Amylopsin, the starch-digesting enzym, appears to be very similar to ptyalin in its power to digest carbohydrates. Amylopsin completes the digestion of starch that was begun by the saliva. It acts on starch with great activity. One part

of amylopsin can change forty thousand times its bulk of starch to glucose. This can act only in an alkaline solution, and if any abnormal fermentation takes place in the digestive tract, producing a large quantity of acids, the digestion of starch is stopped. It is interesting to note that this enzym is entirely absent from the pancreatic juice of infants. This explains why infants cannot digest starch.

Comparison of trypsin and pepsin

The second enzym to be considered in the pancreatic juice is trypsin. This is a substance distinct from pepsin, but its action is the same. The chief distinction is that trypsin acts in an alkaline solution, while pepsin acts in an acid solution. Trypsin is much more energetic in its digestive power than the pepsin of the gastric juice. It completes the digestion of proteids that is begun in the stomach, and converts all proteids into soluble forms. A number of forms of proteid that are not acted on at all by the gastric

juice are readily digested by the trypsin of the pancreatic juice.

Fat digestion and absorption

The fat-digesting enzym of the pancreatic juice is steapsin. This is the principal fat-digesting enzym of the body. This substance has power to split fats; that is, to convert them into fatty acids and glycerin of which they were originally composed. This fatty acid then combines with the alkalis of the bile and of the pancreatic juice to form soap. Soap is soluble, and passes through the walls of the small intestines in this form. Having passed through the walls of the intestines, soap is again changed into fat. The probable reason for which Nature adopts such a complex process for the absorption of fat, is because fat is insoluble. If the intestinal walls were so constructed that fat-globules could be taken directly through them, they would also be open for the entrance of germs and other foreign substances.

Fat is not acted on by the gastric juice. This explains why the process of frying is so unwholesome. Frying causes a thin film of melted fat to spread over the surface of the starch and of the proteid atoms, with the result that these atoms cannot then be properly acted on by the saliva and the gastric juice, and therefore cannot undergo the preliminary changes necessary to normal digestion. Fat, taken in its natural form, does not interfere with other digestive processes.

Frying fat unwholesome

INTESTINAL JUICES

In addition to the digestive juices that are poured into the small intestines from the pancreas and the liver, there is a juice which is secreted from the walls of the intestinal cells. This is called intestinal juice or succus entericus. It is a light yellow fluid with a strong alkaline reaction, due to the presence of sodium carbonate.

One action of the intestinal juice is to change sugar and maltose into glucose, which is then absorbed directly into the blood.

THE SECRETION OF DIGESTIVE JUICES

Within the past few years many remarkable discoveries have been made in regard to the secretion of the various digestive juices. Until some ten or fifteen years ago it was believed that the secretion of the digestive juices depended wholly upon the presence of food in the alimentary canal. The recent discoveries in this branch of physiology are to be accredited chiefly to Professor Palloff, a Russian scientist, and his co-workers. The facts that are now known regarding this part of Nature's work are essentially as follows:

Recent discoveries concerning digestive juices

The secretion of the various substances which make up the digestive fluids of

the body depend upon two kinds of stimuli:

1 Direct nerve stimulus from the central nervous system

2 The chemical stimulus on the walls of the digestive organs

Depending upon either or both of these sources of stimulation, the digestive juices of the body are regulated in quantity, and what is much more worthy of note, in their actual chemical composition. Thus it will be readily seen how far-reaching in its effect upon scientific dietetic treatment is the knowledge of the influence of various foods, quantities, and combinations.

Comparative digestibility of foods

Professor Palloff's discoveries throw some very important light on the comparative digestibility of foods. The former method of estimating the digestibility of food was first to analyze the food, and

then to analyze the intestinal residue, and subtract the undigested remnant of each particular class of food from the amount originally eaten. By such means it was possible to show that certain foods were, say 80 or 90 per cent digestible, as the case might be. By this method no allowance was made for the amount of nutrition or material that was consumed by the body in the digestion of these particular foods. According to these investigations, milk and meat were about equally digestible. It was not known that the digestion of milk requires only a small fraction of the energy that is necessary to digest meat, or proteids from vegetable sources. Thus it is obvious that when it is desirable to get a large amount of available nitrogen into the system, with as little expenditure of energy as possible, milk is a food par excellence. This is very logical inasmuch as the sole purpose of milk is food for animal life.

The amount of acidity in gastric juice that must be secreted for the digestion of meat is much in excess of that required for a given amount of vegetable food. The amount of acidity required is greatest for milk, second for meat, and least for bread. The digestive energy required is greatest for bread, second for meat, and least for milk. From this we learn that starchy foods are unsuitable for those who are afflicted with hyperchlorhydria or supersecretion of hydrochloric acid, as the excess of acid prevents their digestion by neutralizing the alkali of the intestines.

Comparative acidity and energy required in digestion

The saliva secreted when nitrogenous food is eaten does not contain as much ptyalin as that secreted when starchy food is consumed; for this reason the thorough insalivation of starchy foods is much more important than that of meat, milk, and eggs. Some authorities have recently

Insalivation of starchy foods and meats

advised that people should not chew meat at all, but should swallow it as do carnivorous animals. This advice, however, is not altogether sound. In the first place, man is not a carnivorous animal, and the gastric juice of the human stomach does not act as rapidly on flesh foods as does the gastric juice of meat-eating animals, but if meat be taken into the human stomach, either in large or in small quantities, decomposition may take place before digestion has proceeded far enough to prevent the action of micro-organisms.

Mental influence upon digestive fluids

The mental influence upon the secretion of digestive fluids may originate from thought, or may be brought about reflexively by the sight, or by the smell of food. All are familiar with the experience of having one's mouth water at the sight of a particularly appetizing dish. Many of us have undergone the same experience by merely thinking of some particular food of which we are fond.

Digestive juices vary with different foods

Scientific investigation has shown that the secretion of saliva is only an example of what takes place in the other digestive organs. The experiments of the ingenious Russian scientist, heretofore mentioned, prove that the act of tasting and of swallowing food was the chief factor in determining the secretion of the juices from the stomach-walls. In a series of operations upon dogs, performed by skilled surgeons, certain interesting facts were observed. The esophagus was severed and made to open externally so that the food swallowed did not pass into the stomach. The secretion of gastric juice was then determined in the case of different foods which were taken into the dog's mouth and swallowed, but which did not reach the stomach. Not only did this act of pretended feeding start a flow of gastric juice, but the juice secreted in the case of different foods was especially adapted to the particular food, according

to the general principle which we have already discussed.

These facts emphasize several important considerations regarding our diet:

1 We should eat slowly and get the whole taste out of food by thorough mastication, because taste largely controls the secretion of the digestive fluid

2 We should not disguise our food by high seasoning

3 Foods that do not require the same digestive principles should not be taken at the same meal

Fermentation is the term generally applied to changes that take place in such food substances as carbohydrates, due to the growth of bacteria, while the term putrefaction is applied in a similar way to

"Fermentation" and "Putrefaction" compared

the changes taking place in nitrogenous or proteid materials. Both of these chemical changes are exceedingly harmful.

ABNORMAL CHEMICAL CHANGES IN THE DIGESTIVE ORGANS

Bacteria chief causes of abnormal changes

Under this heading we will consider the chemical changes which take place in the human alimentary canal, which are not beneficial or necessary to normal digestion. The cause of the most important abnormal changes in the contents of the stomach and the intestines is the presence of living micro-organisms called bacteria.

In the lesson entitled "Evolution of Man," a general survey of the history of man's development from lower forms of life is given. In this general work I do not elaborate extensively upon the method by which evolution proceeds, but those who are acquainted with the writ-

ings of Darwin, and other evolutionists, are familiar with the phrases "the survival of the fittest," and "the struggle for existence."

As we commonly think of "the survival of the fittest" in animal life, we picture the death-struggle of the captured animal, or the fight for food in times of scarcity, or, if it be in the case of plants, the crowding or the struggling for soil and sunlight. We can apply the same principle to bacteria and to other microscopic forms of life.

"Survival of the fittest" among bacteria

Bacteria, while minute masses of unconscious protoplasm, are, by the laws of growth and reproduction, struggling for existence just as truly as are the more conspicuous forms of life.

Because of the invariable presence of greater or less quantities of bacteria within the intestines of all ordinary animals, some scientists insist that their presence is in some way necessarily

related to the life of the animal, and is probably beneficial.

New-born animals, however, are free from bacteria, and the bacterial germs found in the more matured animal must, therefore, have been taken into the alimentary canal with food. Ingenious scientists have taken new-born guinea pigs, and have kept them in sterile or germ-proof compartments, giving them filtered air to breathe, and absolutely sterile food. These pigs lived and thrived through the experiment as did their fellows outside the bacterial-proof dwelling. This is considered good evidence that bacteria accumulate in the digestive organs of all animals, not for a purpose connected with animal physiology, but because in order to digest and to assimilate food, conditions are established which are so nearly like those required for bacterial growth, that bacteria are produced, or take advantage of the favorable condi-

Experiments proving accumulation of bacteria

tions, just as weeds, if given a chance, thrive in a cultivated field.

Not all bacterial growth is harmful

I have already referred to the antiseptic or germ-destroying properties of the gastric juice, and to other secretions of the digestive organs. This would suggest that the growth of bacteria is undesirable from the standpoint of man's welfare. There are many species of bacteria growing in the human intestines, hence we cannot say with certainty that all this bacterial growth is harmful, as, in order to determine this, the resulting waste-products of each particular species of bacteria would need to be considered separately. We can, however, make the general statement that bacteria are abnormal, or foreign to the human digestive canal, and that their presence is detrimental to human welfare.

Micro-organisms give off various substances as waste-products of their growth, dependent upon the species of bacteria,

and the material in which they are growing. Thus the waste-products of the yeast-plant are carbon dioxid and alcohol.

In the alimentary canal there exists an abundance of carbohydrate and proteid substances which form excellent food material for numerous species of bacteria.

Waste-products of bacterial fermentation

The substances produced by the growth of these various kinds of bacteria are numerous. They include the gases, carbon dioxid, hydrogen, hydrogen sulfid, marsh-gas or methane, and ammonia. Butyric, lactic, and other acids, together with alcohol, are also produced as a product of bacterial fermentation in the intestines. Perhaps the most detrimental of all are the substances produced by the bacterial putrefaction of proteids, of which indol and skatol are the two most important.

Under ordinary conditions the bacteria themselves do not penetrate the intestinal walls, and their evil influence would be confined to mechanical disturbance of gas

in the digestive organs, and to the destruction of a portion of the nutritive material of food, were it not for the fact that these harmful and poisonous waste-products I have mentioned, are soluble, and hence pass through the intestinal walls with the digested food material, into the blood, and are thus distributed throughout the body.

Solubility and distribution of bacterial waste-products

It has been observed in the presence of intestinal congestion, where the food lies in the intestines for an abnormally long period, that the amount of these harmful nitrogenous decomposition products excreted by the kidneys, is considerably increased, proving that these products have circulated throughout the body.

Arterio-sclerosis, or the hardening of the walls of the arteries, which has for many years been recognized by scientists as one of the principal causes of old age, comes from two causes:

Causes of hardening of the arteries

> (1) The over-consumption of starchy foods, especially of the cereal group; and (2) by the continued presence, in the blood, of small quantities of poisonous material which gradually destroys the protoplasm of the arterial walls, and causes them to be replaced by a degenerate form of tissue.

For example, alcohol and the poison of syphilis are prolific causes of the hardening of the arteries. If the diet were balanced so as to avoid excesses of starch and these toxic substances, the hardening of the arteries would not take place.

The poisons produced in the intestines by bacterial decomposition, superinduced largely by overeating, are absorbed into the blood, and undoubtedly their action is similar to the other poisons herein mentioned. Thus they become a most potent factor in the cause of old age and pre-

Overeating an ultimate cause of old age

mature death, being practically universal among all civilized tribes.

Numerous other disorders or dis-eases can be traced to this same general cause, and the subject of the poisonous products of fermentation and decomposition in the intestines will therefore be constantly referred to throughout this work.

From the deductions that have been made it is clearly evident that any system of feeding which will reduce the amount of bacterial growth in the intestines, would be desirable and beneficial to mankind, while foods and habits of life that increase the amount of such poisons are to be guarded against as detrimental to both health and life.

The growth of bacteria decreased by scientific eating

Overeating is perhaps the greatest of all dietetic errors in bringing about a condition which favors excessive intestinal fermentation. Overeating causes stomach prolapsus, thus reducing its

Overeating primary cause of fermentation

mixing or peristaltic activity. This retards the process of emptying, called digestion, which is the primary cause of fermentation. Under this condition the antiseptic properties of the stomach-juices are reduced, and the bacteria from the fermenting food is vastly increased. The food, passing from the stomach in a fermenting state, produces gas in the intestines, with the resultant ills that follow, such as vertigo, dizziness, irregular heart action, and usually intestinal congestion or constipation.

THE DECOMPOSITION OF FOOD

Sugar destroys putrefying bacteria

The putrefaction of proteids in the intestines may be reduced by the liberal consumption of fresh sweet fruits. The preserving qualities of sugar depend upon the fact that putrefying bacteria cannot live where sugar is abundant. The bene-

ficial effect of sweet fruits in reducing bacterial decomposition in the intestines, is due to the presence of relatively large quantities of sugar and of organic acids. Sour milk is known to have a prohibitive influence upon putrefaction in the alimentary canal. This is due to the milk-sugar, which has been changed to lactic acid. This explains why clabbered milk, which contains a considerable portion of sugar changed into lactic acid by the action of souring bacteria, is especially beneficial in preventing intestinal putrefaction. Professor Metchnikoff, of the Pasteur Institute of Paris, became so enthusiastic upon this discovery that he proclaimed sour milk to be a remedy for old age. While Metchnikoff's enthusiasm is perhaps somewhat premature, yet the idea is worthy of much consideration.

Sour milk a preventive of intestinal putrefaction

We do not need, however, to seek for any one specific remedy against intestinal

decomposition, but should study the selections, combinations, and proportions of our food at each meal with the view of reducing to the minimum the growth in the alimentary tract.

Proper feeding chief factor in reducing bacterial growth

DIGESTIVE EXPERIMENTS

It is well known that only a portion of the food taken into the alimentary canal is digested and absorbed into the circulation. It is obvious that the undigested food plays no part in the process of metabolism, therefore it is necessary to know the amount of the various food elements that are digested. For this reason we will notice briefly the method used in making digestive experiments.

The food eaten for a certain period of time is analyzed and weighed, and the intestinal excreta, corresponding to the quantity of food under study, is also weighed and chemically analyzed. The

Determination of the amount of food the body uses

difference should show the amount of food actually digested.

There are several serious difficulties in the way of making accurate digestive experiments:

Quantity of feces and time consumed in passing food through the body

1. It is very difficult to determine the quantity of feces (intestinal excreta) that corresponds to a given quantity of food. A digestive experiment is usually conducted for a period of about one week, the man or animal being given a spoonful of lampblack at the beginning and at the close of the experiment. The lampblack being a finely powdered form of pure carbon, is insoluble in the digestive juices, hence passes through the body without change, thus blackening or marking

the feces at the beginning and at the end of the test period. The subject under experiment should be given the same diet for a few days before and after the experiment, so that the error due to the inability to accurately separate the feces will be reduced to a minimum.

Measuring the digestible portion of food

2. The digestive juices, and especially the bile, pour considerable material into the alimentary canal which cannot be distinguished from the undigested elements of food. However, it is fair to assume that when large quantities of body-proteids are poured into the alimentary canal, and passed out with the feces, this amount of matter is wasted by the body, hence

should be charged against the food which stimulated the secretion. For example: If grain causes a large secretion of digestive enzyms, it is no more than fair to say that grain is less digestible than milk, which wastes less body-matter in its digestion.

Certain foods may either aid or hinder digestion

3. A further difficulty with the accuracy of digestive experiments, and one to which in the past too little attention has been paid, is the influence upon the digestibility of one food by the presence of others. Some foods, such as fruits, aid the digestion of other foods, while in many cases the presence of a certain article seriously hinders the digestive

The mono-diet system

process of all. This emphasizes the great necessity for observing the laws of chemical harmony in combining our food at meals, and it also emphasizes the importance of limiting the diet to the fewest number of things possible, which in the opinion of the writer will lead inevitably to the mono-diet system, especially in curative or remedial feeding.

Difficulty of determining amount of undigested food

From the standpoint of the above difficulties, all digestive experiments thus far made are only approximately correct, and we are forced back to the conclusion that if we obey the laws of nutrition, Nature will give us her highest result expressed in endurance. If a single article of diet is taken by a man who is accustomed to large quantities of a highly

varied bill of fare, the digestive process will not act in the usual way. On the other hand, if several articles such as nuts, grains, and milk are taken at one time, it will be impossible to determine what percentage of the proteid or of the fat from the three various sources remains undigested in the intestinal residue, hence no accurate results can be shown regarding the digestibility of each particular food.

MECHANICS OF DIGESTION

Chemistry is not the only factor in the digestive function that is to be taken into consideration. The mechanical condition of food, when it is taken into the digestive organs, very greatly influences the chemical process that takes place.

Condition of food influences chemical action

This involves the question of masticating or subdividing the food into small particles. The greater the dissolving

surface, the more rapidly will solution take place. If the substance being dissolved is a firm particle, the digestion or solution will take place only on the exterior surface, and the interior of the particle, however small, will remain practically unchanged. This is what occurs when food materials such as grains and nuts are taken in an uncooked state, as mastication does not dissolve them, but only divides them into small, distinct particles.

Necessity for thorough mastication

If, however, the grain be subjected to prolonged heating with water, partial solution takes place. The entire mass becomes mushy and permeated with moisture. When such a mass is brought in contact with the digestive fluids, it mixes or disintegrates with the fluid, just as molasses would mix with water. The result is that the whole mass of material is subjected to the action of the digestive fluids at once, with the result that the

Action of enzyms during digestion

mass is passed from the stomach too quickly, causing congestion in the small intestines, or the whole is arrested, and fermentation and decomposition take place. In normal digestion, the enzyms are continuously secreted for a period of several hours. They begin work on the outside of the food particles, dissolving the substances gradually. Thus the enzyms are continuously used up, and the digestion proceeds slowly, but naturally, yet as fresh enzyms are continuously being secreted to act on the newly exposed surfaces, active and complete digestion is constantly taking place.

Predigested "breakfast foods"

The alleged predigestion of certain proprietary foods has neither scientific basis nor virtue. That the juices of some fruits which are already in the form of glucose, can be immediately absorbed into the tissues without any digestive process, does not prove that the mushy cooking, malting, and other forms of

so-called predigestion are beneficial. The so-called "predigested breakfast foods" are not and cannot be prepared by any process for final digestion, but are in an intermediate state between starch and glucose. They are composed of a semi-soluble starch, gummy dextrin, and perhaps a little maltose which has a tendency to disturb and to interfere with the normal process of digestion.

Comparative digestibility of cooked and uncooked starch

I do not advocate the use of uncooked grain, but I wish to correct a popular error in regard to the digestibility of uncooked cereal starch. Nearly all works on physiology and diet make the statement without reserve that raw starch is indigestible. This theory has been established by putting samples of cooked and uncooked starch into two test tubes, and treating them with some digestive enzym. The cooked starch, being soluble, is all exposed to the digestive enzyms at one time, and started on its way through

the numerous changes in the complex chemical process of changing starch into glucose, while in the sample of uncooked starch, the digestive enzym attacks the particles from the outside, and slowly digests or eats off the exterior of the starch grains. After a given length of time the chemist adds iodin to the two test tubes. With starch, iodin gives a blue color. In the test tube containing the cooked starch, all of which has undergone a certain amount of digestion, no blue color is discerned, for no pure starch is left, while in the other tube, in which some of the particles remain unchanged, owing to the fact that Nature does all her work slowly, a blue reaction is of course obtained, and the chemist proclaims that uncooked starch is indigestible.

At one of the United States Experiment Stations in the state of Kansas, a comparison of two diets, consisting chiefly of several varieties of grains, was recently

made. The diets were alike in every respect with the exception that in one instance all the grains were boiled for two hours, while in the other case they were taken in an uncooked state.

Government experiments with cooked and uncooked grains

In the case of the uncooked grains, no starch whatever passed through the body in an undigested form. In the case of the cooked grains, the same results were found; that is, no starch was found in the intestinal residue. Other substances, however, remaining undigested in the cooked diet, were much in excess of that in the uncooked, yet no starch was present. In the case of cooked grains, the digestive processes may start with more rapidity than in uncooked grains, yet they are not thoroughly completed, and various decomposition products occur, as well as undigested proteid, which is not likely to occur with foods taken in their natural state.

Moreover, if uncooked starch be taken in excess of the digestive capacity, and passed through the body wholly unchanged, no harm results. The starch grain, in its unchanged state, is a fine, white glistening granule, and its presence in the digestive tract would have no harmful effect upon the body functions. Without solution, no material can have any effect upon the physiological processes, except by irritating the mucous surfaces of the digestive organs; in the latter respect, starch granules are harmless.

Uncooked starch harmless

With the exception of articles that are in solution, the condition in which all foods should enter the digestive organs is in finely divided, yet distinct particles, and not in pasty or gummy masses. In this latter form "bolting" is encouraged, and mastication greatly discouraged.

Condition in which food should enter digestive organs

THE MUSCULAR MOVEMENT OF DIGESTIVE ORGANS

Another point to be considered in digestion, and which may well be classed under the mechanics of digestion, is the muscular action or peristalsis of the alimentary tract. The best example is the swallowing action observed in the throat of a horse, or of a cow, when drinking. At each swallow, what appears to be a lump goes down the throat. This is a wave-like relaxation of the muscular walls of the esophagus, followed closely by a muscular contraction. This is the action that takes place in the intestinal tract, and that which Nature employs to move the contents along toward the final point of excretion.

Peristaltic movement in alimentary canal

A very fascinating and scientific demonstration may be performed in the following manner: A cat may be given food mixed with some such substance as bis-

X-ray examination of peristalsis

muth subnitrate, which is opaque to X-rays. Upon placing the animal under an X-ray during digestion, this peculiar peristaltic motion can be observed, one "swallow" passing rapidly after another down the alimentary tract.

This method of investigation has also shown that peristaltic action stops immediately in the case of fright, or anger, but is shown to proceed with regularity during sleep, contrary to the antiquated idea that digestion ceases when sleep begins.

Milk for relieving constipation

Peristaltic action in the lower parts of the alimentary canal is stimulated by taking food into the stomach. This explains the laxative action of such foods as fruits, or, sometimes, milk, taken at frequent intervals. When all other methods fail, constipation can oftentimes be relieved by taking a glass of milk every thirty minutes until four glasses have been consumed.

Moisture and peristaltic action

The longer food remains in the intestines, the more completely is the water absorbed from the residue. The object to be obtained in relieving constipation is to increase the moisture and the peristaltic action. Whatever will accomplish these things will relieve and perhaps cure intestinal congestion.

The subject of intestinal congestion and purgative medicines will be discussed at length in Lessons IX and XI, Vol. II, p. 375 and p. 436, respectively.

Lesson VI

CHEMISTRY OF METABOLISM

LESSON VI

Chemistry of Metabolism

Meaning of metabolism

Metabolism is a word used to describe all processes that take place within the body from the time food is absorbed from the digestive organs until it is passed out of the body through some of the excretory channels. To be more accurate, it means the sum of both the anabolic, or constructive, and the catabolic, or destructive, processes that continually go on in the animal body.

Distinction between anabolism and catabolism

The process of metabolism is chiefly one of tearing apart, or of breaking down, complex chemical substances into simpler forms of matter. Formerly, all processes in animal life were considered to be those of tearing down, or of simplifying, chemical

compounds; while plant life was considered to be chiefly the process of building up complex substances from simpler forms of matter. This distinction, however, is rather general with many exceptions. The two terms, "anabolism" and "catabolism" are sometimes used to distinguish between the processes of building up complex chemical compounds, and the oxidizing or tearing down of such compounds by effort or activity. Thus, the formation of muscular tissue from the digested proteid materials would be a process of anabolism, or construction, while the conversion of glucose in the muscle-cells, into carbon dioxid and water would be an example of catabolism, or destruction.

Catabolism a process of oxidation

The process of catabolism is, in general, one of oxidation; that is, oxygen is added to the chemical compounds taken from the food we eat, forming simpler substances which are excreted from the body as

waste-products. Oxidized carbon in the body forms carbon dioxid; hydrogen is oxidized into the form of water, while nitrogen leaves the body in the more complex and incompletely oxidized substance known as urea, the chemical formula of which is COH_4N_2. A small portion of nitrogen leaves the body in the form of uric acid, $C_5H_4N_4O_3$.

Why muscular work produces warmth

The process of anabolism usually absorbs energy or heat from the surrounding material, while catabolism produces heat as a result of oxidation, as do ordinary fuels. This explains why muscular work warms the body.

We may study metabolism best by considering the two purposes food serves in the animal body, as follows:

FIRST — THE BUILDING OF ACTUAL BODY-TISSUE

Every atom composing the human body is constructed from food. The number

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and the proportion of the various chemical elements composing the body are well known, and were it not for the fact that the body is constantly casting out old cells and waste-products, the problem of nutrition would resolve itself into the simple process of supplying the body with the materials needed for growth.

Formation of new tissue and destruction of old

We could analyze an adult man and a new-born infant, and know that the infant, in order to reach maturity, would need to add to its body so many pounds of oxygen, carbon, sulfur, iron, etc. The problem of nutrition, however, is more complex. Not only must we consider the formation of new tissue, but we must also allow for the rebuilding of the old, and for all those processes of vital activity that involve the consumption of food material and the destruction of body-tissue. Nor can this allowance be accurately proportioned from the analysis of the body, because the various ele-

ments composing it do not change with equal rapidity. Thus, a man in a harvest field might pass through his blood in one day ten or fifteen pounds of oxygen (in the form of water and carbon dioxid), which would amount to ten per cent of the oxygen contained in his body, but if he should take calcium or fluorin to the extent of ten per cent of that contained in the body, death from poisoning would speedily ensue.

We can better understand the use of foods and the process they undergo in building the body by considering separately each class of food material from the time it is absorbed from the alimentary tract until it is excreted from the bowels, or from the lungs and the kidneys, or deposited in the body as bone, fat, or tissue.

SECOND — THE GENERATION OF HEAT AND ENERGY

The second function, or rather group of functions to be considered in the study

of metabolism is the generation of heat and energy. If the reader will recall what was said in Lesson II, regarding the production of heat by the process of oxidation, he can more clearly comprehend the method by which heat is produced in the animal body. However, as heat is only one form or expression of energy, these two subjects—heat and energy—should be considered together.

Heat and energy produced by oxidation

The production of heat and energy in the body occurs almost entirely through the oxidation of food. All three classes of foods, namely proteids, carbohydrates, and fats can be oxidized to produce heat.

Heat, a measure of energy

Energy may be mechanical, chemical, electrical, or thermal. The conservation of energy, which is one of the fundamental laws of science, teaches that no energy can be lost, but can only be changed into other forms. This being true, and because all energy can be changed into heat, we use heat as a measure of energy.

The unit of heat, and consequently of energy, that is used by scientists is the "calory," which is the amount of heat required to raise the temperature of one thousand grams of water one degree on the centigrade thermometer scale. The energy in food is measured in calories, as will be learned from the explanation given in the lesson entitled "Vieno System of Food Measurement."

The "calory," a unit of heat

The Vieno is merely a unit especially convenient in measuring the energy in food. In order that this energy may be drawn upon or liberated in the body, it is necessary for the food to pass through the process of metabolism, as heretofore described.

Liberation of energy through metabolism

THE MEASURE OF HUMAN ENERGY

Food may be considered as a storehouse of latent or potential energy.

Because of the law, the conservation of energy, which shows that no energy in the universe can be lost, it is possible to study, with great accuracy, the energy produced in, and given off by, the human body.

Intake and outgo of energy accurately determined

The method by which energy is measured in accurate scientific experiments is by means of a device called the respiratory calorimeter.

This device is a small room, the walls of which are impervious to the transmission of both heat and air. In this room a man or an animal may be kept for a period of several days. The air breathed, the food eaten, the body-heat given off, the waste-products excreted, and the mechanical work done, are all measured with the greatest scientific accuracy. Many interesting results have been obtained from the investigations conducted with this wonderful scientific

How energy is measured

device. These experiments will not be given in detail in this work, but it might be remarked that experiments within the respiratory calorimeter have proved absolutely that the law of "the conservation of energy" works in the human body in the same manner as in the scientist's laboratory. Moreover, such experiments have confirmed the results of the oxidation of various foods in the laboratory, and have given us data from which to compute the stored energy in various food substances. It has thus been found that the amount of energy yielded to

Energy yielded from one gram each of proteids, carbohydrates and fats

the body from one gram of proteid is 4.1 calories, and from one gram of carbohydrates 4.1 calories, while one gram of fat oxidized in the body yields 9.3 calories, which is more than twice that yielded by the proteids and the carbohydrates.

Since it has been proved that the laws established in the laboratory also apply

to the human body, it is not necessary to conduct expensive experiments upon the human subject in order to ascertain the amount of energy in some new food. The food may be analyzed chemically, and the energy computed according to the above figures, or a sample of the food may be burned with an oxidizing agent in the laboratory, and the heat measured. This latter process consists simply of oxidizing a gram of the food in a closed steel cylinder which is immersed in a known amount of water at a known temperature. The increase in the temperature of the water, multiplied by the weight of the water in grams, gives the number of calories contained in the substance tested.

Simple method of finding number of calories in any food

METABOLISM OF CARBOHYDRATES

The products produced by the digestion of carbohydrates are absorbed from

the alimentary canal in the form of glucose and smaller quantities of levulose, and acetic, butyric and lactic acids. This glucose passes into the blood-vessels of the intestines. These blood-vessels unite to form the portal vein which supplies blood to the liver.

Products formed in the body from digested carbohydrates

The chief function of the liver is to regulate the sugar contained in the blood. The liver converts this glucose into glycogen and also acts as a reservoir in which carbohydrates are stored in the form of glycogen until needed by the body. From this glycogen, glucose, or blood-sugar, is again produced when the consumption from the circulation is greater than the supply. Moreover, the liver possesses the power to produce glucose when no carbohydrates are eaten, as glucose can be produced from proteids. The percentage of glucose in the blood remains, or should remain about level,

Conversion of glucose into glycogen

averaging .15 of 1 per cent. It may seem odd at first that the quantity of glucose in the blood remains so nearly level, when the quantity absorbed from the digestive organs, and that utilized in work, is so variable. The control of sugar in the blood is of very great importance in the body-metabolism or life-processes.

Percentage of glucose in blood

The chief use of glucose, and of other forms of digested carbohydrates is in the formation of heat and energy. Glucose is oxidized chiefly in the muscles, producing carbon dioxid, water, and some lactic acid. Another function of glucose in the blood is to build up or form fat. Fat is a form of stored food which is not so readily available for use as are glycogen and glucose.

Uses of glucose in the body

To use a homely figure of comparison, the energy-producing substances of the human body—glucose, glycogen, and fat—may be compared to the movement of

merchandise in ordinary commerce. We could say that the glucose of the blood is as merchandise in the hands of the people, ready to be consumed. The glycogen of the liver would represent goods in the hands of the retailer, while the fat which is stored in larger quantities would be represented by merchandise in warehouses.

Fat produced from carbohydrates

Many interesting experiments have been conducted to prove that fat can be produced from carbohydrates. For instance, during a given period of time a pig was fed daily upon food containing half a pound of fat, and gained during the period nine pounds of fat. Such facts prove beyond all possibility of doubt that carbohydrates are converted into fat in the animal body.

METABOLISM OF FAT

Fat, when absorbed from the digestive tract, is in the form of fatty acids and

glycerin, but immediately recombines into its original form after it has passed through the intestinal walls. This fat then enters the lacteals, which unite to form the thoracic duct. This duct or tube empties its contents into one of the large veins near the heart, whence it is distributed throughout the body. The fat of the blood is not regulated to a definite amount, like the sugar content. After a meal, very heavy in fat, the blood for a time is whitish in appearance, due to the numerous minute globules of fat taken into the circulation.

Body-fat may be absorbed directly from food

The fat of the body may be deposited directly from food-fat. This can be verified if an animal that has been starved until its own body has been greatly reduced, be fed upon some particular form of fat. The fat immediately deposited will then have the peculiar characteristics of the fat taken with the food. Thus a starved dog that has been given

a heavy diet of tallow will deposit fat which will contain a large quantity of stearin and palmitin, and consequently have a higher melting point than normal dog fat. Ordinary animal fat, as has been shown in Lesson IV, is composed of various fats, each of which is a distinct chemical compound.

Human fat not identical with food-fat

The distinction between tallow, lard, olive-oil, and human fat, is chiefly due to the various portions of stearin, and olein, which composes the mixed fat. In normal cases, where fat is deposited at the usual rate, the body-fat is of uniform composition regardless of the food-fats. The reason human fat is not identical with food-fat is because the body has selective power in depositing these fats. Thus, if the sole source of fat which a man takes in his food is tallow, the fat-depositing cells in the human body would refuse a certain proportion of the stearin, depositing a larger percentage of olein,

thus giving a softer or more liquid fat than that which was supplied in the food. The excess of stearin would be consumed in the production of heat and muscular energy.

When the consumption of glucose in the muscles becomes greater than the supply available in the blood, and from the glycogen of the liver, body-fat must be consumed. This explains why exercise reduces obesity.

Why exercise reduces obesity

The method of preventing, or of curing, obesity, is a double process:

1 The diet is selected and proportioned so as to reduce the amount of ingested fat

2 Exercises are prescribed to consume the fat that has accumulated

Of all food materials, fat is the least changed by digestion, and has no par-

ticular function in the life-processes except the storing of energy. More body-energy can be stored in a pound of body-fat than in any other form.

Fat, the chief source of energy

From these deductions it is evident that carbohydrates and fats perform very similar functions within the body, and can, in a large measure, replace each other as a source of heat and muscular energy.

METABOLISM OF PROTEIDS

Owing to the fact that the tissues of the normal body are constructed chiefly from proteids, the metabolism of proteids or nitrogenous foods is of very great importance. When we realize the fact that muscle, blood, brain, nerves, cartilage, tendons, the various internal organs and the tougher material of the skeleton

Importance of proteid or nitrogenous foods

are only various forms of proteid material, and must contain their proportions of available or organic nitrogen, we can understand why nitrogenous foods form a distinct class that must be considered by themselves. Only the mineral deposits of the bones and the teeth, and the globules of fat that are deposited as a source of stored energy represent the nitrogen-free class of substances within the animal body.

THE USE OF PROTEIDS IN THE BODY

Proteids as tissue-builders

The first use Nature makes of proteids in the body is in the actual adding to or increasing of body-tissue. When an emaciated young man from the city goes to work on a farm and gains twenty pounds, the cells of his muscles have actually increased in size and number. This requires proteids, which can be

obtained only from the nitrogenous material in food. The growth during early life is due to an actual increase in the size of all the organs of the body, and is merely an accumulation of proteid substance.

Proteids form the nitrogenous part of the body

The second use of proteids, and the one which, in matured life, is of more importance than those already referred to, is in the formation of the various nitrogenous products which are produced in connection with the different processes of the body and which are destroyed by the function of life. For example, the pepsin of the gastric juice is a nitrogenous substance which can be formed only from proteids. All digestive enzyms and other substances in the muscles, nerves, and in the various organs throughout the body are of a nitrogenous nature, and in their formation and use a certain amount of proteid material is consumed. When the digestive enzyms are formed from

proteids, they consume more than their own weight of proteid material.

Proteids replace worn-out cells

The third form in which proteids may be consumed in the body is in the actual replacement of worn-out cells. The skin, the hair, and the mucous or lining membranes of the body-cavities are constantly being cast off on the external surface, new cells being formed underneath. When cells within the interior of the body have become injured, or have passed their usefulness, they are removed by the phagocytes or white blood-corpuscles, and must be replaced by other cells. In the case of bacterial infections, as tumors, boils, or contagious dis-eases, the bacteria feed upon the proteids of the blood. The white blood corpuscles are destroyed in the conflict, or effort to remove the intruders, and all these substances must be replaced by proteids from food.

THE ACTION AND THE COMPOSITION OF PROTEIDS

The gain or loss of body-proteids is indicated by the gain or loss of nitrogen.

Determination of income and outgo of nitrogen

The income of nitrogen can be ascertained by analyzing the food. The outgo of nitrogen is computed by analyzing the products excreted from the body. If the body at the beginning and at the end of an experimental period is carefully watched, and the income and the outgo of nitrogen determined, we can compute the amount of gain in the body that is nitrogenous tissue. The other gain or loss of body-weight must be fat. These calculations cannot be made exact, owing to the amount of food and water that may be in the digestive organs at the time the various weighings are made.

We have learned that in the digestive tract foods are converted into a soluble form of proteid known as peptone. The purpose of this conversion and the fine

subdivisions of food produced by the various digestive juices are to reduce it to a form which will readily pass through the walls of the alimentary canal.

Why proteids are converted into peptones

This is all that was known about proteid metabolism until within very recent years. The older scientists followed proteid digestion until the soluble peptone stage was reached, at which point all track was lost of the chemical changes and processes until the nitrogen was again excreted by the kidneys in the form of urea.

Nitrogen and urea

No scientist attempted to explain how the radically different proteids, such as egg-albumin, milk-casein, and wheat-glutin could appear in the body as blood-globulin, brain-lecithin, or as a myosis of the muscles.

The history of all these investigations cannot be fully explained here, but the discussion must be confined to that

which actually takes place in the metabolism of proteids.

Proteids, as the student will remember, contain carbon, hydrogen, oxygen, and nitrogen, and sometimes small quantities of sulfur, phosphorus, or iron. These forms of proteids are now known to be chemically changed, by the digestive enzyms of the intestines, into simpler compounds containing these same elements.

Composition of proteids

These simple nitrogenous substances pass into the liver. Just as the liver regulates the supply of blood sugar, so it regulates the supply of nitrogenous compounds in the blood. A certain amount of proteid-forming material is passed through the liver, and goes on to perform the various functions for which proteid is utilized in the body. All nitrogenous material in excess of the amount required by the body is secreted by the liver, and

How proteids may form body-fats

the nitrogen, together with a portion of the carbon, hydrogen, and oxygen, is split off, forming urea, which is excreted by the kidneys. The remainder of the proteid substance, having been robbed of its nitrogen, is now essentially the same as carbohydrates, and goes to form glucose or blood-sugar, which may in turn form body-fats.

Excess of proteids harmful

In the light of this explanation, we can understand several things already mentioned. It has been stated that proteid is the most essential food material of the body because it alone contains the nitrogenous compounds from which the body-tissues, and the chemical enzyms which control all living processes, can be constructed. But we now see that as important as is a supply of proteid materials, any excess above the body-needs is immediately turned into glucose and urea. The glucose, though useful to the body, could be taken in a simpler and less

expensive form, while the urea is a waste-product, harmful to life, and must be immediately excreted by the kidneys.

The nitrogen that is actually used in the body serves a different purpose from that which is split off from the excessive proteid taken as food. The food proteid is simply split by the chemical addition of water, much the same as starch and other carbohydrates are changed into glucose. The proteid that is really used by the body is oxidized, and is excreted by the kidneys chiefly in the form of creatinin and uric acid.

FOOD STANDARDS

Incorrect interpretation of scientific data

The term "dietary standard," as it has been applied in the past, means the quantity of the several nutrients that should be taken by the human body under its varying conditions. During the past

twenty-five years, many investigations have been made in this country, Europe, and Japan, regarding the amount of foods consumed by various groups of people. All the facts gathered, which include more or less accurate records of the foods eaten by many thousands of individuals under all circumstances and conditions of life, are invaluable scientific data, but the interpretation that has been placed upon these interesting observations is one of the most conspicuous blunders made by the scientific world. Whether this criticism should fall wholly upon the men of science, who made these investigations, or upon the people who misinterpreted their meaning, is perhaps an open question; but the fact remains that from the general teachings in physiologies, and from popular bulletins published by the National Government, very incorrect ideas have been widely spread respecting the amount of food required to maintain life and health.

Data of foods consumed daily by various people

In order to give the reader some idea of the results obtained, when data is kept each twenty-four hours, of the amount of food consumed by various people on the conventional diets of civilization, I will select at random some of the results that have been recorded in these investigations, and will give in the Vieno System the approximate results. (See "Vieno System of Food Measurement," Vol. III, p. 639):

	Vienos	*Decigrams Nitrogen Consumed*
California Football Team	66	375
New England Rowing Club	40	255
Wealthy Class in American Cities...	30	250
U. S. Army Rations	37	200
Farmers, Eastern U. S.	34	160
Skilled laborers, U. S. Cities	40	220
Alabama Negroes	34	145
Japanese Peasants	20	100

From such records Government standards have been roughly approximated.

Atwater's Government Standards

The standards published by the Government, computed by Prof. Atwater, and commonly known as the Atwater standards, are as follows, expressed in vienos:

	Vienos	*Decigrams Nitrogen Consumed*
Man at hard muscular work	55	280
Man at hard work	41½	240
Man at moderate work	34	200
Man at light muscular work	30½	180
Man of sedentary habits	27	160

The Atwater standard for women is estimated to be four-fifths of the amount of food required for a man under similar conditions.

It is generally recognized by investigators that these so-called standards are faulty, but by mutual agreement it

seems that they have been accepted as the best that could be given. They lack accuracy because the men who prepared them lacked experience. Accuracy can come only from experience gained in the practical work; that is, in prescribing food, and combinations of food, for people under all the varying conditions of age, climate, and activity, and having these people report, at stated periods, the results of their dietetic prescriptions.

Faulty standards due to inexperience

The average person eats what is set before him and asks no question about nitrogen and energy; nevertheless, advice so universally distributed as the Government Dietary Standards must exert much influence and have a considerable effect upon the habits of the people. Obviously the correctness of these standards is of vital importance to the health and the welfare of the nation.

Importance of correct dietary standards

What a dietary standard should contain

A dietary standard should tell the quantity and the proportion of food required to keep the human body in its very best working state. The great error committed by the man who planned the above-named standards has been that he assumed that an average of what a man *does* eat is a criterion of what he *should* eat in order to maintain the best mental and physical condition. A greater error could not have been made. *Our feeding instincts have been lost in the chaos of civilization.* Both our appetite and our food have been perverted. We have been trained to want or to crave intoxicants, stimulants and sedatives; we have learned to relish things that have no food value, and we have grown to dislike the best food that nature produces, and to accept many of her worst. Dietary standards, therefore, made up from the conventional eating habits of the people, merely endorse their errors and pass

them on to future generations. The work, therefore, of the true scientist is to point out these errors and to prescribe a remedy.

Man is a creature of habits, and civilized man is a creature of a great many bad habits. The argument that the average amount of food eaten is the amount that should be eaten falls under suspicion at once when we consider the fact that by a similar line of reasoning we could prove that the use of tobacco is necessary because the majority of men use it, or that slender waists are necessary to good social standing because a few million women so consider them.

We are creatures of many (bad) habits

The idea has been spread far and wide that the diet of the American working man, which is the richest in proteid of any race in the world, is responsible for the greater economic thrift of the American people. It is a matter of history that

American prosperity not due to rich diet

rich diet is always associated with prosperity, but the theory that the diet is the cause of the prosperity is an egregious error. Meat and rich foods gain a hold upon the appetite as do alcohol and narcotics. When nations or cities become wealthy, intemperance in eating is the usual result, but this in nowise indicates that a heavy consumption of food is the cause of a nation's greatness. History recites many instances of the rise and growth of a people to power and prosperity, together with the consequent adoption of excessive and luxurious habits of eating and drinking, only to be followed by physical deterioration.

Excessive food a waste of energy

It is not the quantity of food that is eaten, but the quantity of food that will give the greatest vitality and capacity to do things, that should determine our dietary standards. It is reasonable to assume that this amount would be the least quantity that would maintain activity

without using up the food material stored in the body. All food taken in excess of the amount actually required must be cast from the body at a tremendous expense of energy. To do a given amount of work, or to add one pound of muscular tissue to the body, requires a definite quantity of energy-yielding or tissue-building material, but if more food is taken than the body can use, the excess ferments in the stomach and in the alimentary tract, producing poisonous products which are absorbed into the blood. These poisonous products cause a great number of human ills. The process of eliminating these poisons we call "disease."

Former dietary standards cut in half

The assumption that the correct amount of food that should be taken by the body is the least quantity that will maintain normal body-functions, has been amply proved by recent scientific investigations to be correct. Many years of

experience on the part of the writer have shown that to make food remedial and curative, the old dietary standards must be, roughly speaking, cut in half.

TRUE FOOD REQUIREMENTS

Quantity of food required for various occupations

The degree of energy required by the body depends very largely upon the amount of work or activity it undergoes, hence the amount of food required to supply this activity cannot be accurately prescribed when the degree of required energy is unknown. However, there is a certain amount of work performed by the beating of the heart and in the maintenance of body-heat which can be fairly well estimated. The quantity of energy-yielding food required, each twenty-four hours, for the maintenance of the activities of life is about one vieno for every ten pounds of body-weight. For a man at steady muscular work, such as a car-

penter or a farmer, this quantity should be about doubled. The quantity required by a man of sedentary habits, but who takes regular exercise for an hour or two each day, is about half way between these two amounts. Thus, a man weighing one hundred forty pounds would require one and one-half vienos for each ten pounds, or twenty-one vienos of food each day. These weights apply only to people of normal flesh, who desire neither to gain nor to lose.

The fact that either fat or carbohydrates can be used as a source of muscular energy may be taken advantage of in prescribing dietaries for persons whose digestive organs are so impaired that they cannot digest a normal quantity of either of these nutrients, but who could digest a small quantity of either. This does not mean, however, that the proportion of fat and of carbohydrates in the food can be disregarded. The digestive processes involved are radically

different, hence a suitable proportion of carbohydrates and fats should always be maintained.

Proportion of fat required under ordinary conditions

With a view to guiding in a general way those who wish to adopt a standard of diet for ordinary use, and who consult tables in which fats and carbohydrates are listed separately, I might state that the fat should form about one-eighth the total source of energy, or one-sixteenth the weight of all water-free (solid) food eaten.

Fallacy of lean meat producing muscle

Until forty years ago the idea was held by scientists, and is still a matter of popular belief, that nitrogenous foods are the sole source of all muscular energy. This is quite a natural assumption. Lean meat is muscle. If a man eats the muscle of another animal, by the primitive process of reasoning, he should acquire muscle. This belief among people who are not acquainted with physiological chemistry is almost universal, while the

facts are, the man who eats the muscle of an ox for the purpose of adding strength to his own biceps is acting no more wisely than the college boy who takes calf's brain for breakfast the day before examination.

The fact that nitrogenous foods are not a source of muscular energy has been repeatedly proved by experiments on man and animals too numerous to relate here.

Nitrogenous foods not a source of muscular energy

The sugar and the fat in the blood are taken into the muscle-cells, and there unite with the oxygen brought from the lungs, producing energy. When the body is fed upon proteids lacking a sufficient quantity of other food elements, a portion of this proteid is converted into glucose or sugar, which maintains body-heat and energy. This is what happens in the case of carnivorous animals that have excretory organs especially adapted to the converting and the eliminating of useless or surplus products.

It has been proved that dogs are capable of living for an indefinite period of time upon a diet containing only a small proportion of proteid matter, while maintaining health and increasing in weight. Thus we see that even carnivorous animals require, for the maintenance of the body-functions, a comparatively small amount of nitrogenous material. Their strength and heat-forming elements can be secured from carbohydrates and fats, probably to their actual benefit. It is interesting to note, however, that dogs as a general rule cannot live and thrive on a vegetable diet; a certain amount of animal proteids seems indispensable. The same principle applies to other carnivorous animals. Even ducks and chickens need a small percentage of animal proteids in order to properly thrive and develop.

Small amount of proteid matter required by animals

In order to maintain good health, every person requires a certain amount

of nitrogen, the quantity being governed by activity, exposure, age, and temperature of environment. The growing youth needs nitrogen to supply material for the tissue growth of his body; an emaciated person who wishes to increase weight, a person recovering from illness, or a man who is constantly performing strenuous work, would all require a generous quantity of nitrogenous food.

Conditions governing quantity of nitrogen

The lowest possible nitrogen requirement for one of normal weight has been determined by various methods to be from 40 to 60 decigrams per day. This quantity, however, is the actual amount that is used in the body-processes, and should be increased according to activity or exposure to the open air.

Lowest daily amount of nitrogen required

From the results of numerous experiments under normal activity, the quantity of nitrogenous food estimated to maintain the best bodily condition is about

three-fourths of a decigram for each pound of body-weight; less than one-half of a decigram per pound of body-weight would cause nitrogen starvation, while more than one decigram per pound, except in the cases just mentioned, would result only in thrusting needless work upon the liver and the kidneys, whose duties are to guard the body against the results of incorrect eating. There are certain conditions under which this amount of nitrogen may be exceeded in order to gain definite and specific purposes, but in such cases the nature of the proteid is of great importance. In certain occupations, for instance sedative labor, the most soluble proteids, such as egg albumin (white of eggs), milk, and green peas and beans should be selected; while in cases of heavy manual labor, the heavier proteids, such as nuts, cheese, dried legumes, fish and fowl should be selected.

Amount of nitrogen required by the body

Lesson VII

FOODS OF ANIMAL ORIGIN

LESSON VII

Foods of Animal Origin

An intelligent discussion of this lesson leads us directly into a subject commonly known as "vegetarianism." The question whether man should eat the flesh of animals is especially fascinating for those who give attention to the food they eat. There are many standpoints, however, from which the subject of vegetarianism may be discussed.

Influence of religion on man's food

In the first place, nearly all religious teachings that have wielded such a powerful influence over the civilization and destiny of men, have laid some restrictions upon the flesh-eating habit. Some religions require man to refrain from all animal products, while others interdict only the flesh of certain animals. Coupled

with man's world-wide search for food, these religious teachings have played a conspicuous part in the question of human nutrition.

Vegetarianism from animal's standpoint

The second phase of the question that merits attention is the moral side, or vegetarianism from the animal's standpoint; in other words, the cruelty involved in the slaughter of our dumb friends and helpers, for whose presence here we are largely responsible. That the practises and customs which train humanity in cruelty toward animal life, are to be discouraged, cannot well be disputed, but this phase of vegetarianism is one which is somewhat without the realm of applied food chemistry, hence is mentioned only as a factor in the general discussion.

I will now consider vegetarianisn from the standpoint of true food science, or the welfare of the physical man. It will be observed that in the lesson entitled

"Evolution of Man," one of the first considerations taken up is the scientific discussion of man's natural adaptation to the use of flesh foods. By natural adaptation I mean Nature's evolutionary plan of fitting the physiological organism to the food man is able to procure. The organism of man will, to a certain extent, adapt itself to a given diet within the brief period of one generation, just as, in the long ages of evolution, the digestive organs of any species of animal become adapted to such diet as may be procured. Thus it is of especial importance for us to know the diet of primitive man at a time before his intellectual resourcefulness made it possible for him to gather his bill of fare from the four corners of the earth.

Vegetarianism from standpoint of scientific living

The diet of our related anthropoid apes, of every primitive savage tribe, and of our ancestors, indications of which have been found in fossils and caves—all three

throw light upon the subject. The consensus of these various studies indicates that the original or natural diet of man was one drawn chiefly from the vegetable kingdom, but not entirely so. Fruits, nuts, green vegetables, edible foliage, tubers or roots were all included in man's primitive diet. The foods of animal origin were varied, and consisted of such articles as birds, eggs, shell-fish, many insects, and other forms of lower animal life, of which our modern habit of eating frogs' legs, eels, escargoes (snails), etc., is merely an inheritance.

Primitive diet of man

Since the digestive, the assimilative, and the excretory organs of man have been constructed from, and adapted to, the use of vegetables, it is obvious that the flesh of animals is unnecessary, especially in view of the fact that there is nothing in flesh that cannot be secured from the vegetable world in its best and purest

Why flesh-eating is unnecessary

form. Man's primitive diet does not prove that he is by nature a vegetarian, as is the cow, and therefore entirely unsuited to digest any material of animal origin. The anatomy of man's teeth and of his digestive organs, however, indicates that he is by nature a vegetarian, and that his digestive organs are prepared to dissolve and to assimilate a diet that is somewhat more bulky than that of carnivorous animals, but, on the other hand, less bulky than the diet of animals which subsist wholly upon succulent plants, as do the purely herbivorous species.

Food problem of the Aryan races

Man is by nature a tropical animal, and so long as his habitat was confined to that section, he could live from the prodigality of Nature, but when he began his early migration northward, his food was the greatest problem he had to solve. He was often forced to choose between eating the flesh of animals and death from starvation. It was this fierce struggle for

food, not the character of his food, which exercised both the physical and the mental powers, and caused the Aryan or northern races to think, and therefore to develop into people so much superior to their tropical brothers.

Forced to think and to work, man became civilized

The defenders of flesh food often point to the fact that flesh-eating people have achieved the highest civilization. Man's superior achievement in northern countries can no more be credited to flesh-eating than to the wearing of fur caps or leather boots. To meet the exigencies of his environment, he was forced to think and to work, and thinking and working developed the brain and laid the foundation for his present stage of civilization.

Another reason for the early habit of flesh-eating is found in the fact that in order to sustain the required amount of body-heat in cold climates, a liberal consumption of fat was necessary. Vege-

table fats not being available, his only source of supply was from the body-fat of animals.

Aside from fat, protein is the only nutritive element meat contains. With the variety of vegetable and butter-fats, and vegetable proteids available in this age, supplemented by our knowledge of chemistry as a guide in their use, the consumption of flesh as an article of human food is entirely unscientific and wholly without reason.

Use of meat unscientific

A diet composed exclusively of flesh contains fat and nitrogenous compounds only. These two classes of foods can, of course, maintain life, as was explained in our sixth lesson, as proteid is capable of forming blood, sugar, and body-fat. The fact, however, that the proteid or the fat of meat can be made to fill, in the physiological economy, the place naturally supplied by the carbohydrate materials of

Life MAY BE maintained by meat

vegetable food, does not prove that such a diet is without its harmful effects. The living body has many wonderful provisions whereby life is maintained under unfavorable influences. Just as a blind person develops a sense of touch which in a way acts as a substitute for sight, so the ability of the body to convert either proteids or fats into sugar, may be utilized in cases of emergency, but the using of this emergency or substitute function of the body cannot develop and energize the human machine as well or as perfectly as can a naturally balanced diet. The fact that some people exist largely upon a meat diet does not prove that this is without its handicapping and evil influences, any more than the use of alcohol and tobacco proves that man is benefited by indulging in intoxicants and sedative poisons.

That flesh-eating is largely responsible for the universal desire among civilized people for some form of stimulant has

ceased to be questioned by those who have been placed in a position to make experiments—the source from which all real knowledge is obtained. These conclusions were first forced upon the writer by noticing the gradual decline of appetite for coffee and tobacco in his own case, when he began to subsist upon natural foods. With this hint no opportunity was lost, among the thousands of patients he treated, to observe the effects and get at the truth. If only one or two people had completely lost their appetite for all forms of stimulation, after following a natural food regimen, it might have revealed only an idiosyncrasy. When a dozen undergo the same treatment, with the same results, it leaves but little doubt that the theory may be true, but when many hundreds give the same testimony, through a period of a dozen years' practise, it reveals a truth that cannot be consistently doubted. Such experience

Flesh-eating produces appetite for stimulants

proves beyond doubt that flesh-eating supports and perpetuates the habit of taking distilled and ardent liquors, tobacco, tea, and coffee, and the numerous drugs which, altogether, have done the human race more harm; dethroned more intelligence; sapped from the human economy more vitality; ruined more homes; made more widows and orphans; changed more natural virtue into vice, and caused more sorrow and tears, more failure and fears, than all other agencies of destruction combined.

Since fats and proteids are the only nutrients supplied by flesh foods, we may well ask, "Is meat the best source from which these elements may be secured?"

Flesh food contains unexcreted waste matter

The proteid substance of meat includes all the edible portion of a carcass except the fat. The proteid of meat is more easily and more rapidly digested than the proteid of vegetables. Notwithstanding this fact, there are serious objections to

the use of meat as a source of nitrogen. All flesh food contains the unexcreted waste matter of the slaughtered animal. When the process of metabolism that is continually going on during life is suddenly arrested by death, the effete and decomposing cells, and the partly oxidized waste-products which are still held in the muscle-tissues, are left in the flesh of the dead animal, hence these poisons must be consumed by the flesh-eater in order to secure the meat proteids and fats.

Body-poisons generated by fear

It is now a matter of common knowledge among scientists, and among the more advanced school of pathologists, that the usual conditions under which animals are slain change the chemical constituents of the blood-serum, charging it with a form of poison that to the chemist is as yet unknown, but the presence and the potency of which is attested by its effect.

The method of slaughtering animals in the great abattoirs is especially conducive to the generation of these poisons. The condemned herd is driven to the place of slaughter and killed, one at a time, in plain view of their fellows. These animals are very intelligent and possess remarkable senses of danger. They are as conscious of approaching death as the creature who takes their lives, hence the amount of poisons generated in their bodies is measured by the time they are kept in waiting. Most animals when killed labor under these conditions, and that these mental states render their flesh entirely unfit for human nutrition can no longer be questioned.

Mother's milk poisoned by fear or anger

We find fragments of evidence supporting this theory in the fact that Nature's perfect food—the milk of a nursing animal, or of a nursing mother—can be changed in an instant into a poison by sudden fright, anger, or fear.

Meat a source of autointoxication

Thus we see that in eating meat, we are eating animal waste-material similar to that thrown off through our own body-cells. The waste material in meat being soluble, passes through the walls of our digestive organs, and enters the circulation, where it is added to similar poisons which are constantly being produced within our own bodies. It is the universal law of animal cell-growth that the waste matter of the cell acts as its own poison. When bacteria, growing in a solution of sugar, have excreted alcohol until it forms a certain percentage of the total contents, their activity ceases—they die from poisons thrown off from their own bodies. This is the reason that liquids containing a high percentage of alcohol must be distilled, and cannot be brewed. It is obvious, therefore, that in the consumption of flesh, we are adding to our bodies the poisons that are residual in the body of other animals, and are,

therefore, approaching the conditions under which bacteria kill themselves by autointoxication or self-poisoning.

Plants utilize the carbon dioxid excreted by the animal, and the excrement of animals is in turn used to fertilize our fields. Although one form of life may utilize what is excreted by another form of life, the living thing that cannot get away from the excreted matter of its own activity is poisoned thereby.

Flesh food burdens the excretory organs

The flesh of animals whose physiological processes are almost identical with our own, containing as it does waste-products that have not yet been excreted, must, when taken into the human body, add extra burdens to our excretory organs which are usually burdened with all they can do. Carnivorous animals are especially provided with an excretory system capable of taking care of such matter, but it is unreasonable to expect the excretory organs of man, which are not

adapted to such a purpose, to throw off, in addition to the regular body-poisons, similar decomposing products of other animals.

Flesh-eating will disappear as science advances

It is true that flesh will support, and has supported what is commonly regarded as a high form of anthropoid life (man), but not having the natural standard from which to measure, we do not know how much better the opposite course would have been, or just how much longer one would live under a perfectly natural regimen. The effects of flesh-eating have not been definitely known until recent years, but is now acknowledged by the most advanced authorities to be one of the greatest errors of civilized people, and will, within a few years, disappear from the catalog of human habits, when the great masses of people are made familiar with the chemistry of food, and how to secure vegetable instead of animal proteids and fats.

MEAT

Meat, in the sense the word is here used, includes beef, mutton, pork, and an occasional allowance of wild game. Chemically considered, meat may be divided into two classes, namely (1) flesh or lean meat, and (2) animal fats. The former will be first considered.

1 FLESH OR LEAN MEAT

Composition of lean meat

Lean meat is composed of the muscles of the animal. Approximately it is 70 per cent water, 20 per cent protein, and 10 per cent fat. The protein is composed of connective tissue, which is a tough, fibrous substance that forms tendons, and holds the muscle-cells in place. Chemically, connective tissue is formed of albuminoids, which were discussed in Lesson IV. These substances are some-

what difficult to digest, and are not of very great importance in the human body, as they cannot take the place of true proteid in tissue-formation.

The percentage of connective tissue in flesh depends upon the cut of the meat. As every housewife knows, the cheapest cuts of meat contain a larger amount of this material.

The gelatin of commerce is a manufactured product derived from the connective tissue of animals.

Other forms of protein are globulin and myosin, which form the actual muscle-substance. These elements form perhaps three-fourths of the entire proteid of the animal, and are the most valuable substances of flesh food. A very small portion of meat proteids is formed by the free albumins of the blood, which are mechanically retained in the muscle-cells, the purpose of which is the nourishment of the animal, and therefore are not unwholesome as food.

Another class of nitrogenous substances found in flesh foods is called meat extractives. Though they exist only in quantities of from one to two per cent of the weight of the flesh, they are the most interesting from the standpoint of chemistry, because they are found only in flesh foods, and are products only of cell life, hence not wholesome as food. They are composed of urea, uric acid, creatin, etc., and are similar or identical to the waste-products of human cell metabolism. The amount of these substances contained in flesh depends upon the condition of the animal at the time of slaughter, being much greater in animals slain after the chase, or laboring under fear or abuse.

Meat extractives and their composition

The chemical composition of the different cuts of meat does not vary greatly, except in a greater or less per cent of fat, and no chemical calculation can compute this accurately, as the fat in every cut of meat varies widely.

Prejudice against the hog

Beef and mutton are comparatively the same in both nutritive value and popularity, but the use of pork has been generally condemned the world over. The reason for this is probably explained by prejudices of tradition and religion, rather than by scientific or hygienic knowledge. The prejudice against swine because of the filthy habits of the animal is more a matter of sentiment than of science. It is sometimes the custom among farmers to confine hogs in a pen, and to feed them upon swill and garbage. This makes of the animal a filthy creature. However, when left in the open fields or woods, they are as cleanly in their habits as any of their brother animals. Corn and alfalfa-fed pork is equally as wholesome as beef or mutton, when prepared in a similar manner, and eaten in temperate quantities, while the hog fattened upon acorns and herbs, in his native habitat (the woods), is much more

healthy, and his flesh really superior to most of his brother animals.

2 ANIMAL FATS

Animal fats not a necessity

The use of animal fats as food is a very ancient custom, especially among the northern tribes. This custom was once justified owing to the necessity for the consumption of a liberal amount of fats in cold countries, but in this country where our marvelous system of international transportation places at the door of every northern home the delicious fats from the olive orchards of Italy, France, and Spain, the refined oil from the cottonseed, and more than a dozen varieties of nuts, including the humble peanut, there is but little necessity for the use of animal fats except in the form of butter and cream.

Perhaps the most injurious way in which animal fats are used is in the

Chemical change in frying fats

process of frying, which is much practised in southern countries in the preparation of other food. The chemical change which takes place in fats, when treated in this manner, renders them exceedingly indigestible, and almost wholly unfit for food.

That per cent of animal fats contained in the ordinary meat diet is quite as wholesome as any other element of nutrition secured from animal sources. However, with the splendid supply of vegetable fats civilized people have to draw upon, the use of animal fats cannot be recommended in any form except that of cream and butter, and when we consider the expense of these by comparison with many pure vegetable fats, our sense of ordinary economy would bid us discard them.

The chief distinction between animal and vegetable fats is in the proportion of olein compared with stearin and pal-

mitin. The proportion of the two latter fats is much greater in fats of domestic animals than it is in the human body; this is especially so of tallow. For this reason vegetable fats, which are of a more liquid nature, are more desirable than those of animal origin, especially where we wish to add fatty tissue to the body.

Chemical difference between animal and vegetable fats

COLD STORAGE OF MEAT

A very small amount of the meat produced in this country at the present time is consumed near its place of slaughter. Cold storage plants and refrigerator cars have been constructed for the purpose of preserving meats until they can reach their destination, and to hold them awaiting market advances for the benefit of packers and tradesmen.

Meat in cold storage is slowly undergoing a form of decomposition which is evidenced by the fact that cold storage

meat decays much more rapidly upon its removal from storage than do the same cuts of fresh meat.

Decomposition of cold storage meat

The process of ripening meat in rooms of varying temperatures depends upon this form of decomposition. The natural enzyms of the meat, and the bacteria contained therein, digest a portion of the proteids, forming nitrogenous decomposition products, similar to the above-mentioned meat extractives. Ripened or storage meats contain a much larger per cent of this group of compounds than does fresh meat.

The high flavor and "peculiar rich taste" of ripened meats is produced by these decomposition products, while the decay of the gelatinoid or connective tissue is the primary reason for its tenderness. There are certain species of bacteria that produce more poisonous waste-products than others, and this occasion-

"Ripened meat" a step toward decay

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ally causes the development of ptomains in storage meat.

A choice between two evils

The use of flesh as an article of food is fraught with many serious and scientific objections, but the use of cold storage or ripened animal products is to be condemned from every standpoint of hygiene. Nevertheless, if people insist upon using flesh foods, and economical conditions make it profitable to produce them far from their place of consumption, cold storage methods seem inevitable. The choice between storage meats and home-killed is, in its last analysis, a matter of selecting the lesser of two evils.

CONTAGIOUS DIS-EASES AND ANIMAL FOOD

Rare beef unfit for food

Much has been written as to how, from dis-eased animals, human beings have contracted contagious dis-eases, especially tuberculosis. The risk of such

contagion has in all probability been much exaggerated. Flesh foods are seldom taken in an uncooked form, and dis-ease germs are usually destroyed by the sterilizing process involved in cooking. The cooking process, however, must be very thorough in order to destroy dis-ease germs; that is, the heat must be sufficient to coagulate the proteids. The interior of a rare beefsteak, such as popularly demanded by the flesh-eater, has not reached this temperature, hence this form of meat should be condemned on this ground if for no other.

Perhaps the worst form of dis-ease contamination from fresh flesh food is that of trichinosis. Trichinae are worm-like creatures which have the first stage of their growth in the flesh of swine, and then become encased in a cyst or egg-like structure, which, when taken into the human digestive organs are revived, and the trichinae then bore their way through

Trichinosis

the walls of the digestive organs, completing their growth in the human muscle-tissue. Trichinosis is one of the most fatal of diseases, but fortunately is not common. Tapeworms owe their origin to a similar source. There are several species of tapeworms; some have their origin in pork, and some in beef.

FISH

Under this heading I will consider fish and other sea-creatures.

Nutrients in fish

The flesh of most fish is quite free from fat, and consists almost entirely of water and proteids. It is less concentrated than the flesh of warm-blooded animals, averaging about 18 to 20 per cent proteids, and 60 to 70 per cent water. The percentage of ash in fish is also somewhat greater than in any other flesh food. The popular idea that fish is good food for the brain originated in the fact that

analysis of some fish shows a considerable percentage of phosphorus, which substance is also found in the brain. There is no reason to believe, however, that the liberal use of fish would develop or produce an excess of brain-tissue. Any well-balanced diet contains ample phosphorus to nourish the brain.

Fish as brain food

The true science of human nutrition lies in the knowledge of selecting, combining, and proportioning food according to age, climate, and work. When this is done, the tendency of the body is to eliminate dis-ease and to assume normal action; this accomplished, every part of the anatomy shares in the general improvement.

My theory advanced against the use of meat because of nitrogenous decomposition products, holds true with fish, though in a somewhat limited degree. The decomposition products of cold-blooded

Fish superior to flesh of mammals

animals are not identical with those of mammals, hence their consumption as food does not add to the percentage of human waste-products so directly as do other meats.

Oysters and clams unfit for food

Oysters and clams, which are generally eaten uncooked, are recommended by many authorities as valuable sources of proteid. The serious objection to their use, and especially uncooked, is the fact that they are grown in the sea-water around harbor entrances which are flooded with sewage, and hence they are likely to be contaminated with typhoid, or similar germs. The actual food value in shell-fish is quite small. They contain only about ten per cent of proteids, and are scarcely worth considering as a source of nutrition.

POULTRY AS AN ARTICLE OF FOOD

The objections that I have made against the use of the flesh of fish and

mammals as an article of food may also be assessed against the use of domestic and wild fowls. There are a few special points, however, in favor of poultry as food that are worth special consideration.

The production of chickens and other domestic poultry is one of the most prolific industries in America, and is of great importance to the general public because it is capable of being carried on in communities too thickly settled for the economic production of beef and other meats.

Poultry superior to the flesh of mammals

Another point to be observed in the use of poultry as food is that, because of the ease with which every farmer and villager can keep a flock of chickens, it is possible for him to have fresh meat produced under the most sanitary and hygienic conditions, while if he uses meat as food, he will be compelled to depend upon the various meat products of unknown age and origin, secured from the general market.

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Another reason why the use of poultry, from a hygienic standpoint, is less objectionable than the use of pork and beef is that the quantity consumed is usually much smaller than the amount eaten of these heavy-blooded meats.

For example: When five pounds of beefsteak is purchased in the market, the amount consumed would be almost the full weight of the purchase. If the money were invested in a five-pound chicken, a goodly portion of this weight would be lost in preparing the fowl for the table, while a still further loss would occur in the bones and in the inedible portions, so that the actual amount of flesh consumed would not be more than perhaps two pounds.

According to the old idea of economy and diet, this would be a serious argument against the use of poultry products, but as has been clearly proved in this course of lessons, the most serious criticism that can be urged against the modern bill of

fare is quantity, and especially the use of meat in large quantities, so common among the American people.

Custom vs. hygiene

The chief reason for which meat is kept upon the bill of fare of most civilized people is that of conformity to custom, surely not to that of hygiene. That form of meat, therefore, which is pleasing to the taste, and which has a tendency to reduce the quantity of flesh consumed, is a step in the right direction of true food reform.

EFFECTS OF FEEDING POULTRY

Fattening poultry

The methods of fattening poultry by shutting them in small coops or compartments, and feeding them upon soft mushy foods, is condemned by some writers on the ground that it is unnatural and harmful to the health of the fowls, and therefore the meat cannot be wholesome. In truth, this process, if not carried too

far, will produce a quality of meat less harmful than that of the barnyard and ill-fed poultry. One of the greatest objections to the use of animal food, as already explained, is the presence of the unexcreted waste-products of animal metabolism. The flesh of fowls, fed and fattened in coops, contains the smallest possible quantity of waste or decomposition products, because of the limited amount of motion or exercise they are permitted to undergo. For this reason, when poultry is to be eaten, the whiter the meat the less objectionable it is as an article of food.

Marketing poultry undrawn

The marketing of poultry in an undrawn condition (without the removal of the internal organs), has been much condemned by the public, and the legislatures of some states have passed laws against this practise. This, however, is to some extent a misapplication of good intentions. When poultry is to be killed for

the market by those who thoroughly understand the business, the fowls are left without food for a period of twenty-four hours. Since the digestive processes of these small animals are very rapid, this results in emptying the intestines of most of the fecal matter, which removes the principal objection to the practise. On the other hand, if the fowls are drawn at the time of killing, and several days elapse before their consumption, bacteria gain access to the interior of the carcass and cause very rapid decomposition.

"Hanging" poultry

It is the practise in some oriental and European countries to "hang" poultry for a few days before they are eaten. This process, as in the case of ripened meats, is simply one of partial decay. The enzymotic action taking place in the meat is arrested only by the process of cold storage. Decomposition proceeds slowly until it reaches that point when it is pronounced high-flavored and "ripened."

This is very largely practised in this country at the present time. It is a custom that is instinctively condemned by everyone from the standpoint of both hygiene and aestheticism. The people should demand and force Congress to pass a law labeling all cold storage meats with the date of slaughter, and all canned meats with the date of packing.

Slaughter of game as sport, a step backward

What is true of domestic poultry is also true of all wild game. The amount of actual food contributed to the world by the slaughter of game is exceedingly small. A similar quantity of domestic food could be produced at one-tenth the cost of time and labor, without slaughtering the wild creatures of our forests. The popularity of hunting as a sport, and the idea that the flesh of all wild animals is a rare and dainty article of diet, is merely an illustration of anthropoid inheritance. It is a step backward toward savagery instead of forward toward a higher civilization.

EGGS

Eggs and milk occupy a unique place in the catalog of foods. The purpose for which they were produced in nature throws much light upon their value as food.

As will be learned from the lesson, "Evolution of Man," no living creature exists for the sole benefit of other creatures, but because once created, the inherent struggle of all living matter to survive and to reproduce itself has evolved wonderful and various adaptations. Every organic substance is primarily produced in nature for a specific purpose in the life of its species. The lumber in our houses owes its existence to the plant's struggle for sunlight, which made it necessary for the tree to possess a strong storm-withstanding stem to hold aloft its leaves above the shade of other foliage.

Every form of life exists for itself alone

The leaves and the stems of grass are primarily an essential part of the life

of the plant, and not food for animals. The greater part of the human food of plant origin represents in nature the nutrient material supplied by the parent plant for the early life of the seedling. All grains, nuts, fruits and roots, and tubers are merely modified forms of food material adapted to the rapid nourishment of the young plant.

The starch and the oil of seeds, the sugar of fruit, and the lesser quantities of nitrogen contained in all seeds, are in a more available form for cell-nourishment than would be the original mature portions of plant life.

Milk and eggs in the animal world occupy a position identical to that of seeds and fruit in the plant world; that is, they are created for the first nourishment of the offspring.

In the process of evolution, a fundamental distinction between birds and mammals is in the manner in which the young are nourished. The egg of the

bird supplies sufficient nourishment to develop the young bird to a point where it can exist upon the ordinary food of the adult bird.

The hen's egg must contain all food material necessary to form all portions of the body of the chick, and to supply it for a time with heat and energy.

Composition of eggs

An average egg weighs two ounces; of this weight about 10 per cent is shell, 30 per cent yolk, and the remainder white. The white of the egg is composed of albumin and water. The yolk consists of globulin, egg-fat, and lecithin; this latter substance contains a considerable proportion of phosphorus, and is one of the essential contingents of brain and nerves. The egg-shell contains 13 per cent protein, 10 per cent fat, and one per cent ash.

The younger the animal, the more rapid is the growth of the animal body compared with the amount of energy ex-

pended. For this reason the percentage of nitrogen in milk and in eggs is much too great to form a balanced adult diet, and should be supplemented by articles containing larger proportions of heat-producing materials, preferably carbohydrates.

Milk and eggs not a balanced adult diet

The proteid material of eggs is in a form especially adapted to the construction of new cells. For this reason it is one of the best known foods for use in cases of emaciation, where new tissue is to be added rapidly to the body. An egg contains about fourteen decigrams of nitrogen. Ten eggs, therefore, would supply an ample amount of nitrogen for the daily needs of the average body, were no nitrogen taken from other sources. In feeding patients who are convalescing from fevers or other wasting dis-eases, it is sometimes necessary to prescribe a diet of from ten to twelve eggs daily for a limited time.

Eggs for emaciation and convalescents

The consumption of five eggs a day, when we rely wholly upon this article for animal proteids, is quite sufficient for one performing ordinary labor, when supplemented by one succulent and one tuber vegetable.

MILK

Milk the best animal food

Milk and the various products made therefrom constitute one of the most important groups of food in the modern bill of fare. Milk and eggs are interdicted by some vegetarians, but aside from the sentimental feeling against the taking of any food of animal origin, there are no scientific reasons for such exclusion. Dairy products are free from many of the objections assessed against the use of flesh, and they supply a number of readily soluble, digestible, and assimilable nutrients that, in many respects (curative and remedial feeding),

excel anything that can be secured from the vegetable kingdom.

The composition of cow's milk varies widely. Dairy cows, by long domestication, breeding and feeding, have been brought to a high state of specialization. Some breeds have been so trained, fed, and bred as to produce large quantities of milk. Some Holsteins have been known to produce one hundred pounds of milk per day each, which of course is many times the quantity required for the nourishment of their young. Some Jersey stock have been so bred, raised, and fed as to produce large quantities of butter; in some cases the butter-fat of especially fed Jerseys has been known to run as high as 8 or 10 per cent, whereas the normal fat content of milk is not more than 3.5 or 4 per cent.

Results of special feeding

The average composition of mixed milk from many cows runs about as follows: Water, 87 per cent; lactose or

milk-sugar, 4.5 per cent; butter-fat, 3.5 per cent; ash, .7 per cent; proteids, 3.3 per cent, of which about 2.5 per cent are casein, and .8 per cent albumin.

The commercial value of milk is measured almost entirely by its content of butter-fat. This is because the public knows practically nothing about the food value, or the chemistry of milk, therefore its value is estimated upon that which can be seen, and upon that which tastes best. The chief value of milk as a food lies in the nitrogenous element it contains. Fat can be secured from many other sources.

Value of milk depends upon its nitrogenous content

The nutritive elements of milk from various animals vary according to the natural requirements of the young of various species.

Cow's milk contains too large a proportion of casein, and not enough milk-sugar to meet the natural requirements of the human infant. This subject, however,

will be discussed at length in Lesson XVI on "Infant Feeding," Vol. V, p. 1154.

Coagulation of casein in milk

The casein in cow's milk is coagulated by the hydrochloric acid of the stomach, which forms into lumps or curds, rather difficult to digest. This can be overcome or counteracted in several ways. First, if milk is allowed to sour or clabber, the casein is coagulated by nature, which is really the first process of digestion. In this form it neither burdens the digestion nor causes the supersecretion of hydrochloric acid, which is likely to occur when sweet milk is too liberally used. Second, the sipping and thorough insalivation of milk, by taking it into the mouth with something that requires thorough mastication, insures better digestion and assimilation, and less liability to produce intestinal gas.

Milk will harmonize chemically with all non-acid fruits, cereals and nuts. Milk is in chemical harmony with meat

and eggs, but all of these articles being highly nitrogenous, when taken at the same meal, the portions should be limited to the minimum.

Milk should not be combined with acid fruits, especially those of a highly acidulous character, such as lemons, limes, grapefruit, pineapples, etc. (See Lesson VIII, Vol. II, p. 314.) Neither should it be taken at the same meals with succulent plants, such as lettuce, watercress, romaine, parsley, etc.

Milk for sour or acid stomach

When the stomach has long been overburdened with food, and made the receptacle in which acid fermentation has taken place until the mucous membrane has become irritated or probably ulcerated, there is no food so acceptable as milk. For the common disorder of hyperchlorhydria, which is a term used to describe a condition of chronic sour stomach or supersecretion of hydrochloric acid, milk is one of Nature's best

counteractive food nutrients. (See "Superacidity," Vol. II, p. 418.)

In cases of severe constipation or alimentary congestion, milk should be given as follows:

Milk diet for constipation

Omit breakfast. Begin about 9:30 taking an ordinary glassful of fresh, cool milk every twenty or thirty minutes, until about one and one-half quarts have been consumed. After two or three hours, repeat the same process until about two quarts more have been taken. With each quart of milk, from three to four heaping dessert-spoonfuls of clean, wheat bran should be taken, in thin cream or rich milk. At noon and at evening a few tablespoonfuls of coarse cereal (wheat or rye flakes), might be eaten. They should be masticated thoroughly, and eaten with nuts and a limited quantity of cream. Under this regimen I have known the most severe cases of constipation to yield readily, and the patient

to make a gain in weight of half a pound daily for a period of from twenty to thirty days. If the appetite should rebel against taking milk in this quantity, the amount should be reduced, and a cupful of soaked evaporated apricots taken at night just before retiring, and in the morning, just after rising.

When milk is taken for the purpose of counteracting a congested condition of the bowels, or an irritated condition of the mucous membrane of the stomach, it should be combined with the fewest possible things—one coarse cereal only will give the best results. A large quantity of milk, three and one-half to four quarts taken daily, as above directed, will act as a laxative, while a small quantity will have a tendency toward constipation.

THE ADULTERATION OF MILK

The old method of adulterating milk with water has very largely gone out

of practise, owing to the surveillance of city authorities, and the passing of laws that fix legal standards, which require milk to contain a certain percentage of fats and total solids.

Evil of milk preservatives

The chief form of criminal tampering with milk has been the use of preservatives to prevent souring. Formaldehyde has been used very extensively for this purpose. Formaldehyde is a poison, destructive to all cell life, and has probably been the cause of more actual deaths than any other form of food adulteration.

MILK PASTEURIZATION

Pasteurization, which takes its name from Pasteur, the French bacteriologist, is merely a process of heating milk to about 170 degrees Fahrenheit for the purpose of destroying possible dis-ease germs, and the bacteria that produce fermentation. In this process the milk

is not allowed to come to a boil for the reason that boiled milk is rather "dead" or distasteful, and would readily be detected by the public. It is quite evident that any method of Pasteurization, which would kill bacteria, would also cause coagulation of the protoplasm and the albumin of the milk, and render it much less nutritious, and much more difficult to digest.

Virtue of naturally soured milk

If milk producers and dairymen understood the superior food and remedial value of naturally soured milk, and would exert some effort to educate the public in its use, they would soon establish a new and profitable industry, and would give the dairy business of the whole country a new commercial impetus. The souring of milk can be prevented by cleanliness, which renders Pasteurizing unnecessary. At the time of the Paris Exposition, a dairy farm in Illinois sent pure unpasteurized milk to Paris, which

arrived in an unsoured condition. This was achieved by absolute cleanliness, with the cows, dairy utensils, etc.

CHEESE

Cheese consists of the coagulated casein of milk, together with the fat globules that may be mechanically retained. Cheese is made by coagulating the milk with rennet, which has been extracted from the stomach of a calf, the sugar of the milk being passed off in the whey, and lost.

Schmier Käse or cottage cheese is formed by allowing the milk to sour, and to coagulate by gradual warming. This cheese is usually made from skimmed milk, hence contains practically no fat.

The several processes of making cheese

The cheese of commerce is ripened in various ways. The process of ripening is due to the action of enzyms present in the milk, or to those formed by bacterial growth. Ripened cheese is considered

to be more easily digested than the unripened product. The best that can be said of this process is that the ripening of cheese is perhaps the least objectionable of all processes of decomposition taking place in food proteids. The only benefit that can be claimed is one of flavor, and, in matters of flavor, the appetite for Limburger, and similar cheeses, is at least a cultivated taste that furnishes evidence neither of merit nor of nutrition.

In the manufacture of cheese, the milk, sugar, and a part of the albumin and fat are wasted, and as there are no advantages in taking the milk in this changed form, there exists no scientific reason for the use of cheese when fresh milk can be obtained.

BUTTER

Butter constitutes one of the most wholesome and palatable of all animal fats, and is probably one of the most extensively used articles of food of animal origin.

When the pure butter-fat has been separated from the casein of milk it can be kept sweet and wholesome for a length of time sufficient to transport it, and to pass it through the various links in the chain of commerce, so that it can reach the family table a long distance from its source of production. This, in addition to man's instinctive relish for dairy products, makes butter the most popular fat in the diet of civilized man.

Fresh butter made in the home

In prescribing butter-fat, however, it is advisable to nominate fresh, unsalted, or what is commonly termed "sweet" butter. It is also advisable for the practitioner to suggest that this can be made daily, merely by whipping either sweet or soured cream with an ordinary rotary egg beater until the fat globules have separated from the whey.

Pure butter contains about 3,600 heat-calories to the pound, and therefore constitutes one of the most important

and readily convertible of all winter foods.

If no other fat is used, about two ounces of butter each twenty-four hours is sufficient to give the ordinary body, under a temperature ranging from forty to sixty degrees above zero, the required amount of heat.

OLEOMARGARIN

Oleomargarin is a general term that includes all manufactured preparations of fats which imitate dairy butter.

Oleomargarin is manufactured by combining beef-fat with cottonseed-oil until a product is formed which has a melting point similar to that of butter. Lard is also used in some oleomargarin products. This combination of fats is then churned with either cream or milk and dairy butter is frequently added so as to give to the artificial product the pleasant flavor or odor of dairy butter. There is

much popular prejudice against the use of oleomargarin, but when made under hygienic conditions, and by cleanly methods, it is practically as digestible, and quite as wholesome as the dairy product.